1997-09

Re-assigning homeports for United States Coast Guard medium and high endurance cutters

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THESIS

RE-ASSIGNING HOMEPORTS FOR UNITED STATES COAST GUARD MEDIUM AND HIGH ENDURANCE CUTTERS

by

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September 1997

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE September 1997	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE RE-ASSIGNING HOMEPORTS FOR UNITED STATES COAST GUARD MEDIUM AND HIGH ENDURANCE CUTTERS	5. FUNDING NUMBERS
6. AUTHOR(S) McCarty, Robert T.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Transportation or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*
The Cutter Assignment Model (CAM) is an optimization-based decision aid that recommends relocation of cutters to homeports in order to maximize combined benefits less relocation costs. In 1996, the Chief of Coast Guard Operations identified port assignments of medium and high endurance cutters as an area where the Coast Guard can improve quality of service. A Strategic Homeports Study Team has been formed and has evaluated candidate ports with respect to a variety of criteria, ranging from proximity to mission areas to shore services. The availability and quality of support and services at a port directly influence mission performance. The Coast Guard seeks cutter reassignments to improve those benefits and others associated with clustering like cutters (collocating) while minimizing costs. CAM prescribes optimal assignments for a complete Pacific or Atlantic operating area scenario in a few minutes using commercial software on a personal computer. CAM also accommodates and optimally completes partial restrictions of assignment scenarios to reflect human judgment or some non-quantifiable considerations.

14. SUBJECT TERMS Optimal location, clustering, optimal homeport assignment	15. NUMBER OF PAGES 64
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

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RE-ASSIGNING HOMEPORTS FOR UNITED STATES COAST GUARD MEDIUM AND HIGH ENDURANCE CUTTERS

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Submitted in partial fulfillment of the
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MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1997

ABSTRACT

The Cutter Assignment Model (CAM) is an optimization-based decision aid that recommends relocation of cutters to homeports in order to maximize combined benefits less relocation costs. In 1996, the Chief of Coast Guard Operations identified port assignments of medium and high endurance cutters as an area where the Coast Guard can improve quality of service. A Strategic Homeports Study Team has been formed and has evaluated candidate ports with respect to a variety of criteria, ranging from proximity to mission areas to shore services. The availability and quality of support and services at a port directly influence mission performance. The Coast Guard seeks cutter reassignments to improve those benefits and others associated with clustering like cutters (collocating) while minimizing costs. CAM prescribes optimal assignments for a complete Pacific or Atlantic operating area scenario in a few minutes using commercial software on a personal computer. CAM also accommodates and optimally completes partial restrictions of assignment scenarios to reflect human judgment or some non-quantifiable considerations.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

An optimization-based decision aid is presented that prescribes cutter homeport reassignments that maximize port benefits less relocation costs.

In support of the National Performance Review's goal to improve the efficiency of the federal workplace, the Chief of Coast Guard Operations has identified the port assignments of medium and high endurance cutters as an area where the Coast Guard can improve its quality of service. A Strategic Homeports Study Team has been formed to develop a set of improved cutter assignments. The Strategic Homeports Study Team has identified and evaluated ports with respect to sixteen criteria, ranging from proximity to operating areas to shore services.

The support and services available at a port directly influence mission performance. A port that is well equipped to support a vessel enables that vessel to operate more efficiently. Candidate ports examined in this thesis include, but are not limited to, current homeports, ports in major commercial areas, and ports near United States Navy facilities. Candidate ports need to be capable of basing multiple cutters, to provide logistics and maintenance support, and to be able to accept the relocation of the cutters with little or no new construction or modification.

The Pacific Area command seeks the assignment of 10 high endurance cutters and 5-210' medium endurance cutters while recognizing that missions performed by Pacific Area cutters are, in many cases, cutter type specific. The distinction between the type of cutter capable of patrolling a particular Operating Area (OpArea) is important because the

value of each candidate port differs depending on its proximity to the OpArea and the type of cutter to be located there.

The Atlantic Area command seeks the assignment of 2 high endurance cutters, 13-270' medium endurance cutters, and 13-210' medium endurance cutters. The missions performed in the Atlantic Area are, generally, not type specific, so each port evaluation applies to all cutters.

This thesis presents an optimization-based decision aid, the Cutter Assignment Model (CAM), which amplifies the work of the Strategic Homeports Study Team. CAM uses the exact criteria and candidate port evaluations developed by the study team to determine an optimal set of cutter assignments. CAM maximizes port benefits less relocation costs, and prescribes reassignments for Pacific or Atlantic Area scenarios in a few minutes using commercial software on a personal computer.

The United States Coast Guard currently tabulates the benefit of clustering (collocating) like cutters in the same homeport as a strictly linear additive benefit score of the individual cutter assignment decisions. This view of clustering offers no extra benefit at all when multiple units are located together. However, clustering may offer nonlinear benefits: synergistic rewards may accrue from shared spares, repair facilities, training aids, support, and perhaps even standby redundancy and mission substitution.

Anticipating that clustering may turn out to be an attractive modeling device, CAM accepts an arbitrary clustering benefit score for each number of cutters of a type located at each port. These completely general and unrestricted clustering scores can be used to attract, or repel, cohort groups of any size.

ACKNOWLEDGMENTS

I would like to thank the people whose help and support made this study possible. I begin with my wife, Debbie, and my daughter, Erin. Their constant support was reassuring. I truly appreciate their tolerance of my many absences.

I thank LT Joe Ryan at Coast Guard Headquarters for his endless supply of answers and information.

Finally, I would like to express my deep thanks to Professor Gerald Brown for his patience and understanding. His expert guidance and spirit kept this study on track and guaranteed its success while making it an enjoyable experience.

I. INTRODUCTION

Good cutter locations enjoy high levels of port benefits which facilitate cutter readiness (e.g. proximity to OpArea, maintenance and logistics support, etc.) and improve personnel support (e.g. quality of life, training, etc.). Through cutter reassignments the United States Coast Guard (USCG) plans to realize those port benefits and the benefits associated with clustering like cutters (collocating). Figure 1 motivates the objective of this thesis.

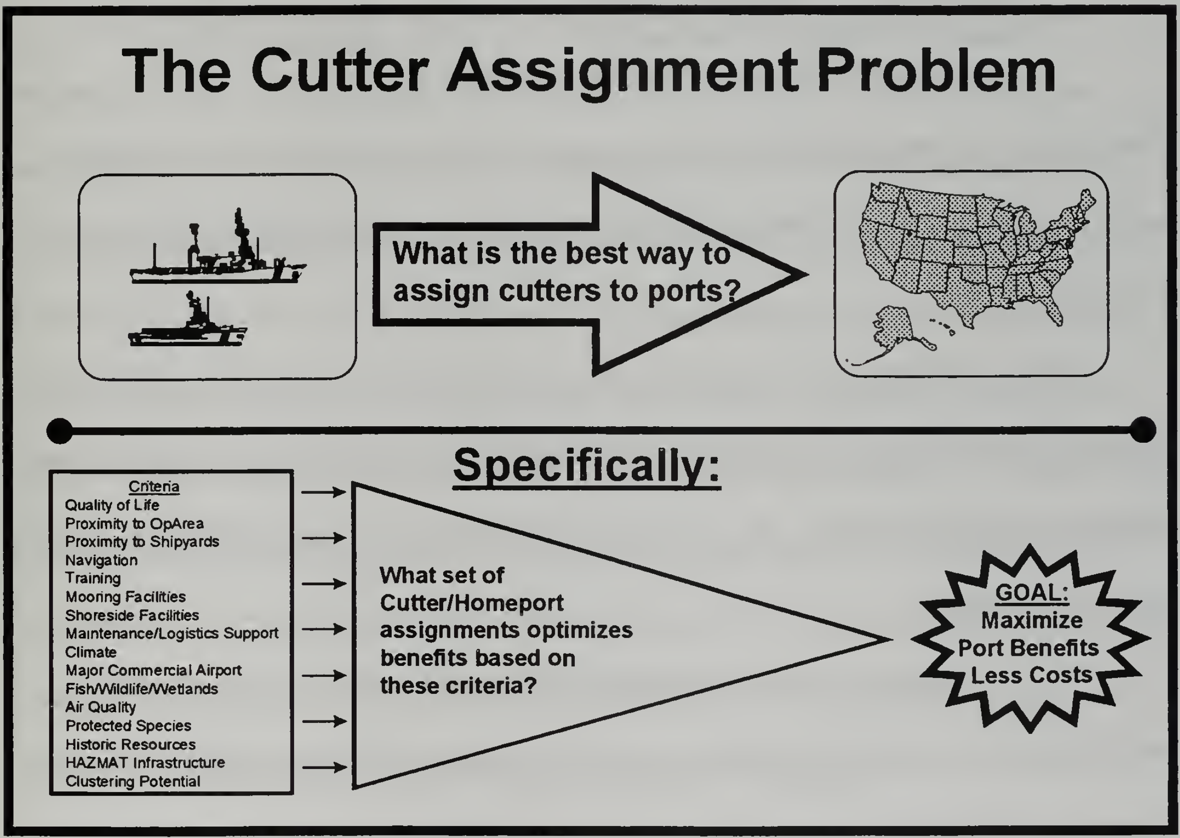

Figure 1. The Cutter Assignment Problem. We seek an assignment (or reassignment) of cutters to homeports. These assignments are based on several criteria and are designed to maximize the benefits achieved from relocating those units less costs.

A. STRATEGIC HOMEPORTS STUDY TEAM

The Coast Guard, in the spirit of the National Performance Review, is examining the efficiency of the service it provides (for a discussion on "Fixing the Federal Workplace" see United States Government, Executive Branch, 1996). The Chief of Coast Guard Operations has identified homeport assignments of medium and high endurance cutters as an area that can be improved. The Strategic Homeports Study Team has been established to perform that examination with the following guidance:

> "To review current and future operational requirements and provide a homeport plan for cutters. To determine the location of cutter homeports that maximizes operational effectiveness and quality of life while minimizing recurring maintenance and support costs." (USCG, 1996a, p. 1)

The Strategic Homeports Study Team is composed of the Allocation and Homeporting subgroups. Each subgroup has constituent members from the Pacific and Atlantic Area commands.

The Allocation Subgroup reviews and prioritizes threat area missions (Search and Rescue, Counter-Narcotic Law Enforcement, Fisheries Law Enforcement, Joint Maritime Exercises Pollution Response, etc.). It also determines resource requirements and current resource utilization.

The Homeporting Subgroup identifies candidate homeports and the criteria, weighting factors, clustering benefits, and sources of information upon which to base their evaluations. Their objective is to "develop a strategic homeport plan that assigns cutters to locations that permit efficient operations, support and maintenance" (USCG, 1996a, p. 1).

B. PRECEDING COAST GUARD WORK

1. Allocation Subgroup

During the author's experience tour, a six week assignment at an operational location that occurs after 16 months of graduate studies at the Naval Postgraduate School, he was assigned to the Allocation Subgroup at the USCG Pacific Area Office of Operations. This group reviewed the number and types of available cutters. Three types of cutters were examined: 378' high endurance cutters, 270' medium endurance cutters, and 210' medium endurance cutters.

The Pacific Area command has 10 high endurance cutters and 5-210' medium endurance cutters. The missions performed by Pacific Area cutters are, in some cases, cutter type specific. For example, winter fisheries patrols in the Bering Sea can only be conducted by high endurance cutters that are capable of enduring the rough weather. Additionally, joint exercises in the Western Pacific Ocean can only be performed by the high endurance cutters due to speed and range requirements. Washington, Oregon, and California fisheries patrols are the exclusive domain of the medium endurance cutters. The distinction between the type of cutter capable of patrolling a particular Operating Area (OpArea) needs to be understood since it has an impact on the level of benefits from certain port assignments. The benefits from assigning a Pacific Area cutter to a port vary depending on port proximity to OpArea and type of cutter assigned.

The Atlantic Area command has 2 high endurance cutters, 13-270' medium endurance cutters, and 13-210' medium endurance cutters. The missions performed in the Atlantic Area are, generally, not type specific so port benefits apply to all cutters.

The Allocation Subgroup has examined cutter needs for each area command. It has discovered a critical shortage of cutters in both area commands. The loss of a cutter by either command would have a serious impact on the ability to carry out assigned missions. The Allocation Subgroup has recommended maintaining the current allocation of cutters (USCG, 1997b, 1997d).

2. Homeporting Subgroup

The Homeporting Subgroup has identified candidate ports to consider for cutter reassignment and developed 16 criteria for evaluating those ports, ranging from proximity to mission areas to shore services. The criteria are based on areas of interest identified during a review of Coast Guard homeport studies conducted to identify Atlantic Area homeports for vessels completing major maintenance availability periods. These studies were driven by time and political pressures which limited analysis. They suggest basic criteria to evaluate ports (USCG, 1996b, pp. 1-3).

The Homeporting Subgroup adopted procedures used by United States Navy staff during the recent cycle of base closures to strategically reassign vessels displaced by port closures. The Office of Cutter Management obtained general procedural guidance from the Navy, but the actual criteria and computational methodology used by the Navy is not available due its sensitive nature (Ryan, 1997).

The Homeporting Subgroup has also developed a scoring plan detailing how points are awarded and the maximum point award possible for each criterion. It has evaluated each candidate port (USCG, 1997b, 1997d).

a. Ports

The support and services at a cutter's homeport are vital to that vessel's mission performance. A port that is well equipped to support a vessel enables that vessel to operate more efficiently. Ports examined include, but are not limited to, current homeports, ports in major commercial areas, and ports near United States Navy facilities. These ports need to be capable of housing multiple cutters, to provide logistics and maintenance support, and to be able to receive relocated cutters with little or no new construction or modification.

The identification of candidate ports begins with the examination of existing ports. Table 1 lists current homeport assignments.

CURRENT CUTTER HOMEPORT ASSIGNMENTS			
PACIFIC AREA		ATLANTIC AREA	
CUTTER	HOMEPORT	CUTTER	HOMEPORT
BOUTWELL (WHEC-719)	ALAMEDA, CA	DALLAS (WHEC-716)	CHARLESTON, SC
MORGENTHAU (WHEC-722)	ALAMEDA,CA	GALLATIN (WHEC-721)	CHARLESTON, SC
MUNRO (WHEC-724)	ALAMEDA, CA		
SHERMAN (WHEC-720)	ALAMEDA, CA	SPENCER (WMEC905)	BOSTON, MA
CHASE (WHEC-718)	SAN PEDRO, CA	SENECA (WMEC-906)	BOSTON, MA
HAMILTON (WHEC-715)	SAN PEDRO, CA	ESCANABA (WMEC-907)	BOSTON, MA
JARVIS (WHEC-725)	HONOLULU, HI	TAHOMA (WMEC-908)	NEW BEDFORD, MA
RUSH (WHEC-723)	HONOLULU, HI	CAMPBELL (WMEC-909)	NEW BEDFORD, MA
MELLON (WHEC-717)	SEATTLE, WA	BEAR (WMEC-901)	PORTSMOUTH, VA
MIDGETT (WHEC-716)	SEATTLE, WA	TAMPA (WMEC-902)	PORTSMOUTH, VA
		HARRIET LANE (WMEC-903)	PORTSMOUTH, VA
ACTIVE (WMEC-618)	PORT ANGELES, WA	NORTHLAND (WMEC-904)	PORTSMOUTH, VA
ACUSHNET (WMEC 167)	EUREKA, CA	FORWARD (WMEC-911)	PORTSMOUTH, VA
ALERT (WMEC-630)	WARRENTON, OR	LEGARE (WMEC-912)	PORTSMOUTH, VA
STEADFAST (WMEC-623)	WARRENTON, OR	THETIS (WMEC-910)	KEY WEST, FL
STORIS (WMEC-38)	KODIAK, AK	MOHAWK (WMEC-913	KEY WEST, FL
		RELIANCE(WMEC-615)	NEW CASTLE, NH
		VIGOROUS (WMEC-627)	CAPE MAY, NJ
		DEPENDABLE (WMEC-626)	PORTSMOUTH, VA
		DILIGENCE (WMEC-616)	WILMINGTON, NC
		VIGILANT (WMEC-617)	CAPE CANAVERAL,
		CONFIDENCE (WMEC-619)	CAPE CANAVERAL,
		VALIANT (WMEC-621)	MIAMI, FL
		DURABLE (WMEC-628)	ST. PETERSBURG, FL
		RESOLUTE (WMEC-620)	ST. PETERSBURG, FL
		VENTUROUS (WMEC-625)	ST. PETERSBURG, FL
		COURAGEOUS (WMEC-622)	PANAMA CITY, FL
		DECISIVE (WMEC-629)	PASCAGOULA, MS
		DAUNTLESS (WMEC-624)	GALVESTON, TX

Table 1. Current homeport assignments of medium and high endurance cutters by area.

Conditions at any port that limit capacity or otherwise make it undesirable have been identified. For instance, shoaling at Cape May, New Jersey, makes that an undesirable port and creates a motive to relocate USCG VIGOROUS (USCG, 1997c).

Candidate ports must be capable of accommodating multiple cutters and different types of cutters. Ports close to United States Navy facilities are obvious candidates due to existing support and logistics infrastructure. Ports with obvious disadvantages (e.g. capacity for only a single cutter) have been eliminated before final evaluation. Table 2 lists the surviving candidate ports by each area command.

CANDIDATE HOMEPORTS	
PACIFIC AREA	ATLANTIC AREA
Alameda, CA	New Castle, NH
Honolulu, HI	Boston, MA
Kodiak, AK	New Bedford, MA
San Pedro, CA	New London, CT
Treasure Island, CA	Newport, RI
Seattle, WA	Cape May, NJ
Port Angeles, WA	Little Creek, VA
Astoria, OR	Portsmouth, VA
Astoria (Tongue Point),	Wilmington, NC
Humboldt Bay, CA	Charleston, SC
Ketchikan, AK	Mayport, FL
Portland, OR	Cape Canaveral, FL
NAS Alameda, CA	Miami, FL
Bremerton, WA	Key West, FL
Everett, WA	St. Petersburg, FL
Long Beach, CA	Panama City, FL
NAVSTA San Diego,	Pensacola, FL
North Island, CA	Mobile, AL
San Diego Sub Base,	Pascagoula, MS
Port Hueneme, CA	Galveston, TX
Pier 90 Seattle, WA	Corpus Christi, TX

Table 2. List of candidate homeports. This is the list of candidate homeports suggested by the Homeporting Subgroup, with 42 candidate ports, 21 per area command.

b. Criteria

The difficulty in selecting among candidate ports derives from establishing and applying criteria to evaluate those ports. This cutter assignment problem is much like the facility location problems faced by private sector companies. The areas of concern for the Coast Guard and for those companies are similar. They include: access to markets (OpAreas), logistics, quality of life, and environmental considerations, to name a few (Schmenner, 1982, pp. 32-40). In his discussion on the United States Army's base realignment and closure efforts, Dell (1997, pp. 1-4) amplifies the importance of careful criterion selection. The criteria the Homeporting Subgroup use in candidate port evaluations are shown in Table 3.

Criteria	Criteria Scoring Criteria Description	Scoring
Quality of Life	Examines housing, commuting, schools, medical facilities, crime rates, cost of living, area employment, public transportation, military exchange & commissary, recreation, higher education	Category score is an accumulation of points in each sub-category. Maximum 100 pts.
Proximity to Shipyards	Examines proximity to shipyards likely to bid on WHEC/WMEC contracts	Score based on distance to shipyards. Maximum 10 pts.
Navigation	Examines distance at sea detail, maximum deviation from track, harbor/basin conditions, potential risks.	Category score is an accumulation of points in each sub-category. Maximum 20 pts.
Training	Examines proximity to "C" schools and FTG/ATG	Score based on distance to training facility. Maximum 10 pts.
Mooring Facilities	Examines dock fees, growth potential, cost for pier maintenance, dredging requirements, crane handling, fuel availability, ammunition handling, hotel services.	Category score is an accumulation of points in each sub-category. Maximum 20 pts.
Shoreside Facilities	Examines parking, storage, MAT building, security, waterfront AC&I backlog	Category score is an accumulation of points in each sub-category. Maximum 20 pts.
Maintenance/Logistic Support	Examines maintenance services available, crane service, fire department, port services.	Category score is an accumulation of points in each sub-category. Maximum 25 pts.
Climate	Examines winter climate conditions, precipitation, and area specific geographic concerns.	Category score is an accumulation of points in each sub-category. Maximum 5 pts.
Commercial Airport	Examines proximity to major commercial airport.	Score based on distance to airport. Maximum 5 pts.
Fish/Wildlife/Wetlands	Examines presence of marine sanctuary, wetlands, impact of dredging.	Category score is an accumulation of points in each sub-category. Maximum 30 pts.
Air Quality	Examines ozone rating or attainment area status.	Category score based on rating. Maximum 20 pts.
Protected Species	Examines presence of threatened or endangered species.	Category score based on extent of presence. Maximum 20 pts.
Historic Resources	Examines historic resources that may be present or impacted.	Category score based on impact on historic resource(s). Maximum 15 pts.
HAZMAT Infrastructure	Examines presence of existing USCG/USN port.	Category score based on extent of USCG/USN facilities. Maximum 15 pts.
Clustering Potential	Examines potential to position multiple cutters together to realize potential economy of scale.	Category score based on number of cutters that can be collocated. Maximum 25 pts.
OPAREA	Examines transit distances to various OpAreas (flexibility in assignments) and location of port relative to cutters traditional OpArea (efficiency in "on station" time).	Category score based on evaluation of sub-categories. Maximum 60 pts.

Table 3. Criteria scoring of a candidate port. There are 16 criteria used to evaluate each port. Each criterion is composed of a number of combined subcriteria. Criteria descriptions are taken from the Strategic Homeports Study Team reports (USCG, 1997b, 1997d). Where possible, local demographic and economic statistics are compared to state and national statistics to establish scoring thresholds (e.g. high school graduates taking SAT, unemployment rates, cost of living rate, crime rates, pollution levels).

Criteria scoring limits the maximum points for each criterion to reflect its importance. For instance, quality of life is an important consideration in the assignment process and is worth as much as 100 points while the port's proximity to commercial airports, a lesser consideration, is worth at most only 5 points. This approach to weighting criteria is useful for this application. If, however, the relative importance of the criteria change, the criteria scoring system will have to be restructured and the candidate ports reevaluated. For a related discussion on weighting see Mattsson (1986, pp. 181-185).

Ports that score high according to these criteria are, naturally, more desirable. Figure 2 shows Alameda, CA, which scores well because of high quality of life, proximity to OpAreas, an established support and logistics base, etc.

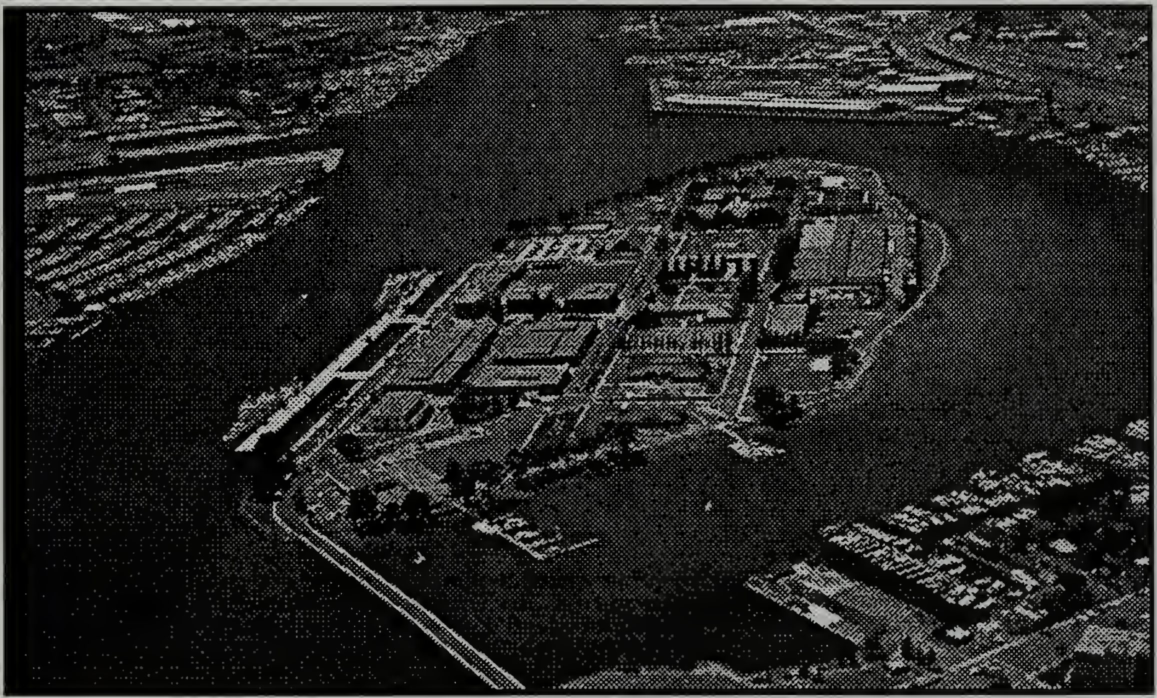
Figure 2. Coast Guard Island, Alameda, CA. Coast Guard Island is the home of the Pacific Area Maintenance and Logistics command that offers extensive mooring and shoreside facilities (note pier and support buildings), and high clustering potential (up to 6 high endurance cutters can be accommodated). The industrial base in the San Francisco Bay area provides access to shipyards in the immediate area, as well as an established HAZMAT infrastructure developed by the many local United States Navy commands. Also, the proximity of this port to the major high endurance cutter operating areas makes it desirable. There is a high quality of life in the area, in addition to a favorable climate, local commercial airports, and high air quality. Ports in Seattle, WA, Newport, RI, Little Creek and Portsmouth, VA, also score high because they exhibit these desirable traits.

C. CUTTERS AND CRITERIA DETAILS

Figures 3 and 4 show the cutters to be assigned and the candidate ports suggested by the Strategic Homeports Study Team, Homeporting Subgroup.

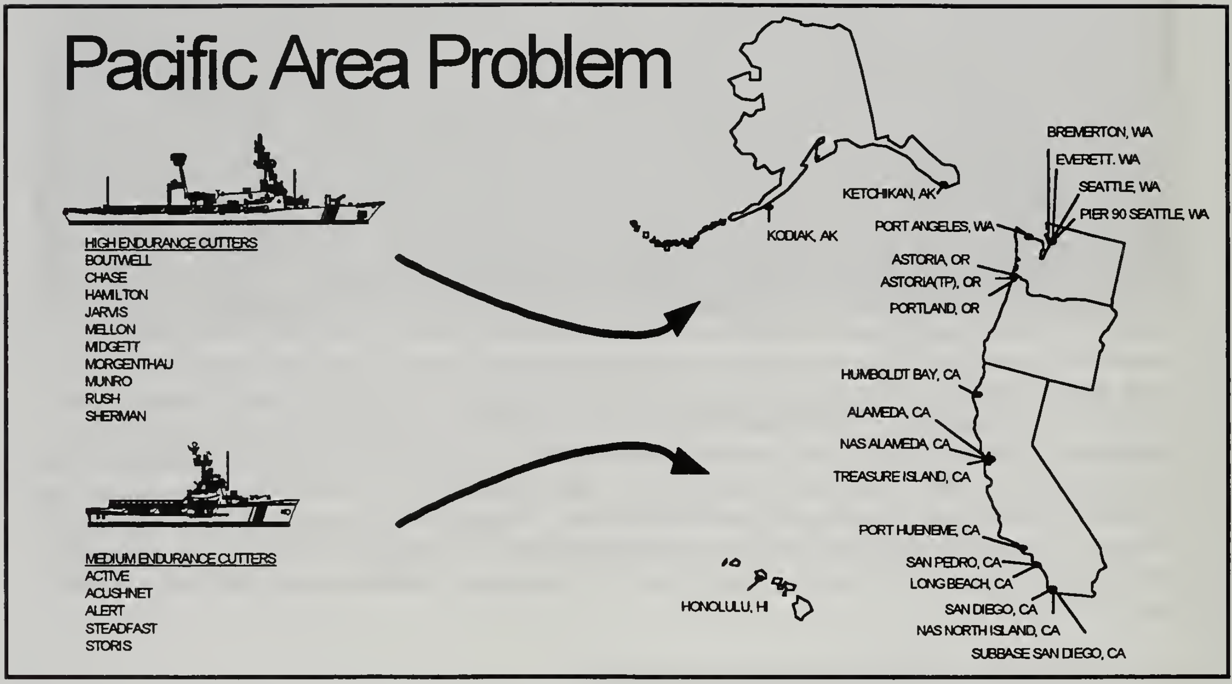

Figure 3. Pacific Area Cutters and Candidate Homeports. We seek assignments for the 15 Pacific Area cutters (10 high endurance cutters and 5-210'medium endurance cutters) to 21 candidate ports. The Pacific Area problem is constrained by limited port availability and relocation costs, and restricted by cutter-type-specific Pacific Area missions and the resulting influence of proximity to type-specific Operating Area.

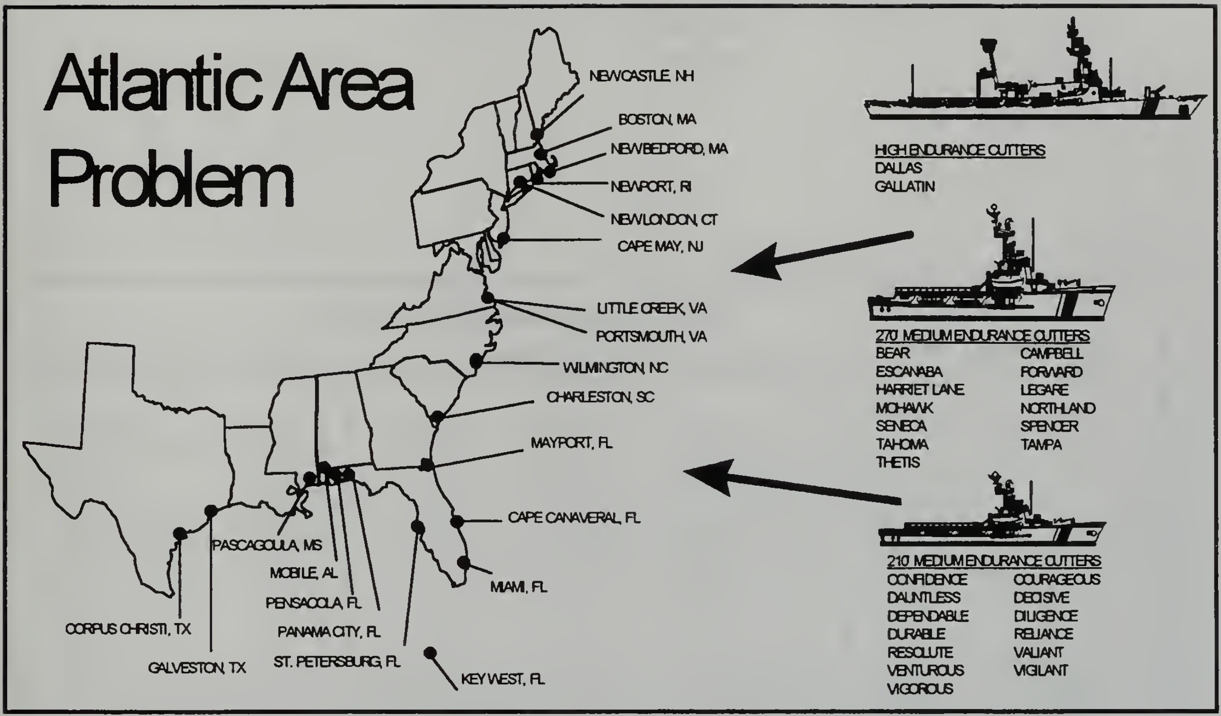

Figure 4. Atlantic Area Cutters and Candidate Homeports. We seek assignments for the 28 Atlantic Area cutters (2 high endurance cutters, 13 270' medium endurance cutters and 13 210' medium endurance cutters) to 21 candidate ports. The Atlantic Area problem is constrained by the need to vacate certain ports and relocation costs, but is simpler than the Pacific Area problem because cutter type specificity is not an issue.

Tables 4 and 5 show the numeric scores reported by the Strategic Homeports Study Team, Homeporting Subgroup (USCG, 1997b, 1997d).

PACIFIC AREA CANDIDATE PORT EVALUATIONS

CRITERIA	MAX POINTS	ISC ALAMEDA	ISC HONOLULU	ISC KODIAK	ISC SAN PEDRO	ISC SEATTLE	GP ASTORIA	GP HUMBOLDT BAY	GP PORT ANGELES	GP AST TONGUE PT	ISC KETCHIKAN	GP PORTLAND	NAS ALAMEDA	NAVSTA BREMERTON	NAVSTA EVERETT	NAVSTA LONG BEACH	NAVSTA TI	NAVSTA SAN DIEGO	NAS NORTH ISLAND	SDIEGO SUBASE	PORT HUENEME	PIER 90. SEATTLE
		HOMEPORTS																				
OpArea HEC	60	27.5	0	45.7	28.2	18.1	22.2	27.4	20.1	22.2	33.1	19.5	27.5	18.1	18.1	28.2	27.5	28.5	28.5	28.5	27.7	18.1
OpArea MEC	60	37.3	0	45.7	35.4	31.2	35	38.9	32.8	35	30.4	32.8	37.3	31.2	31.2	35.4	37.3	35.2	35.2	35.2	35.5	31.2
Quality of Life	100	73	62	51	53	60	58	62	56	62	52	48	73	54	52	48	71	68	68	68	60	60
Proximity to Shipyards	10	10	0	0	2	10	2	0	2	2	0	10	10	10	10	2	10	10	10	10	2	10
Navigation	20	7	11	7	8	17	5	6	13	[illegible]	6	[illegible]	8	10	11	9	8	7	7	8	9	17
Training	10	2	6	0	2	8	8	0	8	0	0	2	2	6	6	2	2	6	6	8	2	6
Mooring Facilities	20	13	16	14	16	13	11	7	11	11	13	8	11	11	5	0	0	6	0	8	11	12
Shoreside Facilities	20	13	10	10	14	11	12	11	12	14	6	13	7	7	4	0	0	6	0	8	6	13
Maint/Log Support	25	22	23	17	21	25	11	6	3	6	15	9	16	14	14	16	16	13	13	12	9	22
Clustering Potential	25	25	5	10	15	15	5	5	0	[illegible]	5	0	25	[illegible]	[illegible]	0	0	0	0	5	5	25
Climate	5	3	5	0	5	1	0	2	3	0	0	0	4	0	0	5	3	5	5	5	5	0
Major Comm. Airport	5	[illegible]	[illegible]	0	[illegible]	[illegible]	1	2	2	2	2	[illegible]	5	2	2	5	5	[illegible]	5	5	2	5
Gen.Fish/Wild/Wet	30	30	30	30	30	27	25	9	22	17	30	25	14	22	30	0	0	22	30	30	30	28
Air Quality	20	20	20	20	10	20	20	20	20	20	20	20	10	20	10	0	0	20	20	20	10	20
Protected Species	20	20	[illegible]	20	10	15	0	0	5	0	20	20	0	5	5	0	0	0	0	0	20	20
Historic Resources	15	10	15	10	10	10	15	15	15	5	15	15	10	5	15	0	0	15	10	0	10	15
HAZMAT Infrastructure	15	15	15	5	0	15	10	10	10	10	10	10	0	15	15	0	0	15	15	15	15	0
Total HEC	400	295.5	230	239.7	229.2	270.1	203.2	182.4	203.1	181.2	227.1	210.5	225.5	206.1	204.1	118.2	145.5	230.5	220.5	230.5	223.7	271.1
Total MEC	400	305.3	230	239.7	236.4	283.2	216	193.9	215.8	194	224.4	223.8	235.3	219.2	217.2	125.4	155.3	237.2	227.2	237.2	231.5	284.2

Table 4. Pacific Area Candidate Port Evaluations. Points are awarded by criterion to each Pacific Area candidate port. Separate totals are reported for medium and high endurance cutters because Pacific Area missions and Operating Areas are type-specific.

ATLANTIC AREA CANDIDATE PORT EVALUATIONS

CRITERIA	MAX POINTS	NEW CASTLE	BOSTON	NEW BEDFORD	NEWPORT	NEW LONDON	CAPE MAY	LITTLE CREEK	PORTSMOUTH	WILMINGTON	CHARLESTON	MAYPORT	CAPE CANAVERAL	MIAMI	KEY WEST	ST PETERSBURG	PANAMA CITY	PENSACOLA	MOBILE	PASCAGOULA	GALVESTON	CORPUS CHRISTI
	HOMEPORTS																					
OpArea	60	0	27	32	32	33	0	40	40	0	23	28	41	0	60	41	29	25	22	21	0	0
Quality of Life	100	0	69	53	66	74	0	77	75	0	65	48	58	0	46	61	54	55	64	54	0	63
Proximity to Shipyards	10	0	10	10	10	2	0	10	10	0	10	0	0	0	0	0	0	2	2	2	0	0
Navigation	20	0	11	13	16	14	0	19	14	0	11	14	14	0	11	9	12	13	4	6	0	10
Training	10	0	0	4	5	5	0	10	10	0	0	10	2	0	0	0	0	0	0	0	0	8
Mooring Facilities	20	0	14	13	18	15	0	16	12	0	12	15	13	0	15	10	11	18	12	16	0	15
Shoreside Facilities	20	0	11	13	16	13	0	15	14	0	19	15	14	0	12	15	13	15	19	15	0	15
Maint/Log Support	25	0	22	7	17	10	0	17	23	0	13	14	9	0	13	14	11	12	14	14	0	15
Clustering Potential	25	0	10	5	25	15	0	15	25	0	25	0	5	0	15	10	5	25	0	0	0	0
Climate	5	0	1	1	1	1	0	2	2	0	2	3	3	0	3	3	3	3	1	1	0	4
Major Comm. Airport	5	0	5	2	2	2	0	5	5	0	5	5	5	0	5	5	5	5	5	2	0	5
Gen.Fish/Wild/Wet	30	0	30	30	30	30	0	17	17	0	25	25	25	0	22	17	25	30	17	22	0	30
Air Quality	20	0	10	10	10	10	0	10	10	0	20	20	20	0	20	20	20	20	20	20	0	20
Protected Species	20	0	20	20	20	20	0	20	20	0	5	5	5	0	5	5	5	5	5	5	0	20
Historic Resources	15	0	10	10	15	10	0	15	15	0	10	15	15	0	10	15	15	15	15	15	0	15
HAZMAT Infrastructure	15	0	15	10	15	5	0	15	15	0	10	15	10	0	15	15	10	15	15	15	0	15
Total	400	0	265	233	298	259	0	303	307	0	255	232	239	0	252	240	218	258	215	208	0	235

Table 5. Atlantic Area Candidate Port Evaluations. Points are awarded by criterion to each Atlantic Area candidate port. Ports earning 0 points are existing homeports that are no longer desirable. These ports are included only to permit calculation of relocation costs.

D. RELOCATION COSTS

Failure to consider relocation costs could result in a cutter being relocated at a cost incommensurably higher than the resulting present value of the increase in benefits (or, worse, cutters could exchange homeports at no apparent cost). The Cost of Base Realignment Actions (COBRA) Model (Brown, 1989) considers costs associated with relocation when estimating a proposed installation closure or realignment. COBRA has been used extensively by the Department of Defense in this capacity (see, for example, Defense Base Realignment and Closure Commission, 1995). Kleindorfer and Kunreuther (1994, pp.415-419) discuss costs associated with locating hazardous facilities.

While a port is not remotely like a hazardous facility, the two have similar cost concerns associated with relocation (e.g. construction and material/personnel transportation). Lacking exact cost information, the relocation cost can be based on the distance of the move.

II. CUTTER ASSIGNMENT MODEL FORMULATION

A mixed integer program is developed here to assign Coast Guard medium and high endurance cutters to ports.

A. VERBAL MODEL DESCRIPTION

The Cutter Assignment Model (CAM) assigns cutters to ports to maximize total, weighted, additive benefits associated with those assignments. The model:

MAXIMIZES: Port benefits (measured by summing port benefits awarded for each cutter assigned to a port, weighted benefits for proximity to OpArea, and weighted benefits for clustering) less weighted relocation costs,

SUBJECT TO: Every cutter shall be assigned to only one port, no port can accept more cutters than it can accommodate, and clustering of like cutter types may have extraordinary benefits.

B. CAM ASSUMPTIONS

The costs of relocating cutters are assumed to increase with distance. For this model, distances between ports (United States Department of Commerce, 1996a, pp. T13-T16; 1996b, pp. T16-T20; 1996c, pp. T21-T25; 1994, p. T-21) are grouped and converted to discrete useable, relocation costs. These distances and the conversion ranges are displayed in Tables 6 and 7.

Distances Between Pacific Area Ports

	PIER 90 SEATTLE	PORT HUENEME	SAN DIEGO SUB BASE	NORTH ISLAND	NAVSTA SAN DIEGO	TREASURE ISLAND	LONG BEACH	EVERETT	BREMERTON	NAS ALAMEDA	PORTLAND	KETCHIKAN	TONGUE POINT	PORT ANGELES	HUMBOLDT BAY	ASTORIA	SEATTLE	SAN PEDRO	KODIAK	HONOLULU
ALAMEDA	807	314	455	455	455	4	374	779	807	4	652	1156	567	677	281	561	807	371	1693	2091
HONOLULU	2409	2176	2278	2278	2278	2091	2236	2381	2409	2091	2331	2383	2246	2279	2372	2246	2409	2236	2230	
KODIAK	1693	2074	2115	2115	2115	1693	2034	1230	1258	1693	1346	742	1261	1128	1412	1261	1258	2034		
SAN PEDRO	1493	60	94	94	94	371	3	1465	1493	371	992	1497	908	1363	652	908	1493			
DEATTLE	1	1433	1228	1228	1228	807	1493	28	16	807	362	659	278	130	526	278				
ASTORIA	567	848	989	989	989	567	908	250	278	567	85	660	1	148	286					
HUMBOLDT BAY	516	595	736	736	736	277	655	498	526	281	371	875	286	396						
PORT ANGELES	130	958	1098	1098	1098	677	1018	102	130	677	232	529	148							
TONGUE POINT	566	847	988	988	988	566	907	249	277	566	86	659								
KETCHIKAN	659	1470	1575	1575	1575	1156	1497	631	659	1156	745									
PORTLAND	362	966	1074	1074	1074	652	992	334	362	652										
NAS ALAMEDA	807	314	455	455	455	2	344	779	807											
BREMERTON	17	1433	1228	1228	1228	807	1493	16												
EVERETT	28	1433	1208	1208	1208	787	1473													
LONG BEACH	1148	60	94	94	94	374														
TREASURE ISLAND	807	314	455	455	455															
NAVSTA SAN DIEGO	1228	154	1	1																
NORTH ISLAND	1228	154	1																	
SAN DIEGO SUB BASE	1228	154																		
PORT HUENEME	1088																			

Distance Conversion:

Miles	Relocation Cost
0	0
1-500	2
501-1000	3
1001-1500	4
Over 1500	5

Table 6. Distances Between Pacific Area Ports. Shown in nautical miles, these distances are converted into a discrete relocation cost ranging from zero to five.

Distances Between Atlantic Area Ports

	CORPUS CRISTI	MAYPORT	MOBILE	PENSACOLA	NEWPORT	NEW LONDON	LITTLE CREEK	GALVESTON	PASCAGOULA	PANAMA CITY	ST PETERSBURG	MIAMI	CAPE CANAVERAL	WILMINGTON	CAPE MAY	NEW CASTLE	KEY WEST	PORTSMOUTH	NEW BEDFORD	BOSTON
CHARLESTON	1440	197	1104	1070	787	725	414	1335	1114	1026	864	434	283	151	501	930	572	429	813	873
BOSTON	2215	1031	1879	1845	86	148	556	2110	1889	1801	1639	1196	1021	807	372	57	1347	571	60	
NEWBEDFORD	2155	971	1819	1785	38	74	696	2050	1829	1741	1579	1136	961	747	312	117	1287	511		
PORTSMOUTH	1776	587	1440	1406	485	423	15	1671	1318	1230	1068	770	639	363	199	514	908			
KEY WEST	880	462	544	510	1261	1199	893	775	542	454	292	151	313	667	975	1290				
NEWCASTLE	2272	1088	1936	1902	143	205	613	2169	1946	1858	1696	1253	1078	864	429					
CAPE MAY	1843	659	1507	1473	286	224	184	1738	1517	1429	1267	824	649	435						
WILMINGTON	1535	315	1199	1165	721	659	348	1430	1082	994	832	529	388							
CAPE CANAVERAL	1206	178	870	836	935	873	567	1101	868	780	618	175								
MIAMI	1031	311	695	661	1110	1048	755	926	693	605	443									
ST PETERSBURG	588	754	377	334	1553	1491	1185	483	250	377										
PANAMA CITY	426	916	193	139	1715	1653	1347	321	200											
PASCAGOULAT	585	613	67	82	1803	1741	1435	476												
GALVESTON	207	1225	496	509	2036	1974	1668													
LITTLE CREEK	1761	572	1425	1391	470	408														
NEWLONDON	2079	737	1743	1709	48															
NEWPORT	2141	799	1805	1771																
PENSACOLA	618	960	89																	
MOBILE	605	994																		
MAYPORT	1330																			

Distance Conversion:

Miles	Relocation Cost
0	0
1-500	2
501-1000	3
1001-1500	4
Over 1500	5

Table 7. Distances Between Atlantic Area Ports. Shown in nautical miles, these distances are converted into a discrete relocation cost ranging from zero to five.

The relocation costs are discretized into five categories, representing "no move" to "a long move", and weighted sufficiently to express that relocating a cutter is not free, but small enough to allow movement. These weights are important: They convert the distance score into a surrogate for the net present value of benefits, from which they are subtracted.

C. DATA REQUIREMENTS

CAM requires:

1. Cutter data, including names, types, and current homeports;
2. candidate port names and capacities;

3. port benefit scores by criteria;

4. OpArea proximity weighting factor (the default is 1);

5. cluster weighting factor (the default is 1); and

6. relocation costs by port.

Cutter data is modest in volume and readily available. The remaining data comes from the Strategic Homeports Study Team, Homeporting Subgroup, findings (USCG, 1997b, 1997d). Relocation costs have been developed in this chapter.

D. MATHEMATICAL FORMULATION

Indices

c	cutter
h, h′	homeport
w	criterion
t	type of cutter (e.g. highc, medc270, medc210)
n	number of cutters (e.g. 0,1,2,3,4,5,6)

Induced Sets

type (c)	type of cutter c (e.g. high, 270' medium, 210' medium)
home(c)	current homeport of cutter c

Data

cap_h	Cutter capacity of homeport h
$qualwt_w$	Homeport quality weighting factor for criterion w
$clusval_{n,t}$	Cluster value of n collocated cutters of type t
$typeprox_{t,h}$	Proximity to OpArea of a type t cutter at homeport h
$portqual_{w,h}$	Homeport criteria scores
$movecost_{h',h}$	Relocation cost of moving a cutter to homeport h from homeport h′
proxwt	OpArea proximity weighting factor
cluswt	Cluster weighting factor
movewt	Relocation weighting factor

Decision Variables

$ASSIGN_{c,h}$	Assignment of cutter c to homeport h
$NUMASGN_{n,t,h}$	Binary indication of number, n, of type t cutters assigned to homeport h
$CLUST_h$	Overall clustering score earned at homeport h
$PORTSCORE_w$	Overall homeport quality score by criterion w
$XOPT_h$	Overall OpArea score by homeport h
PROXCOST	Total relocation costs associated with current set of cutter assignments
PORTBEN	Total port benefits score achieved with current set of cutter assignments

Formulation

$$\text{Maximize} \quad PORTBEN = \sum_{w} qualwt_w * PORTSCORE_w + \sum_{h} proxwt * XOPT_h + \sum_{h} cluswt * CLUST_h - movewt * PROXCOST \tag{1}$$

Subject to

$$\sum_{h} ASSIGN_{c,h} = 1 \ \forall c \tag{2}$$

$$\sum_{c} ASSIGN_{c,h} \leq cap_h \ \forall h \tag{3}$$

$$PORTSCORE_w = \sum_{c,h} portqual_{w,h} * ASSIGN_{c,h} \ \forall w \tag{4}$$

$$XOPT_h = \sum_{c} typeprox_{type(c),h} * ASSIGN_{c,h} \ \forall h \tag{5}$$

$$\sum_{n} n * NUMASGN_{n,t,h} = \sum_{c|type(c)=t} ASSIGN_{c,h} \ \forall t,h \tag{6}$$

$$\sum_{n} NUMASGN_{n,t,h} = 1 \ \forall t,h \tag{7}$$

$$CLUST_h = \sum_{n} \sum_{t} clusval_{n,t} * NUMASGN_{n,t,h} \ \forall h \tag{8}$$

$$PROXCOST = \sum_{c} \sum_{h} movecost_{home(c),h} * ASSIGN_{c,h} \tag{9}$$

$$ASSIGN_{c,h} \in \{0,1\} \ \forall c,h \tag{10}$$
$$NUMASGN_{n,t,h} \in \{0,1\} \ \forall n,t,h$$

Equation (1) represents the total port benefits achieved with the set of cutter assignments. It is the sum of the port quality score, OpArea proximity score, and clustering score, less relocation costs. Weighting factors are available to capture changes in emphasis for port criteria, OpArea proximity, clustering, and relocation cost. For instance, assigning more value to OpArea proximity is reflected in an increase in the proximity weighting factor (the default value is 1) which leads to a higher OpArea proximity score. This will draw cutter assignments closer to OpAreas. Similarly, if the clustering value is found to be higher at Seattle, WA, than at San Pedro, CA, the clustering weight can be quickly modified to be homeport-specific.

CAM has two fundamental sets of constraints: individual cutter assignments and port capacity. Partition equations (2) ensure that each cutter is assigned to exactly one port. Equations (3) ensure port capacities, expressed in number of cutters assigned, are not exceeded (for discussion of the capacitated facility location problem see Mirchandani, 1990, pp. 120-121).

Equations (4) calculate the total benefits achieved for each port quality criterion. Similarly, equations (5) calculate total OpArea score achieved at each homeport.

Equations (6) and (7) convert the binary cutter assignments to each port into a binary indicator of the number of each cutter type assigned to each port. These results are incorporated into equations (8) that calculate the total clustering score for each port. This formulation enables CAM to accept clustering values that vary arbitrarily by the number of collocated cutters of each class.

Equations (9) calculate the relocation costs associated with the cutter assignments.

Specifications (10) stipulate that binary decisions are made.

This formulation is presented with the understanding that efficiency improvements are possible. In particular, equations (4), (5), (8) and (9) can be included in equation (1), reducing the overall number of constraints. This formulation, however, is useful in examining scenarios (e.g. setting thresholds) and reporting results.

E. IMPLEMENTATION OF CAM

CAM is implemented using the General Algebraic Modeling System (GAMS) (Brooke, Kendrick, and Meeraus, 1992) and solved with the XA solver (Sunset Software Technology, 1993). CAM provides a detailed list of assignments of cutters to ports and total benefits for each criterion and port.

III. CUTTER ASSIGNMENT MODEL RESULTS

A. SCENARIOS

We refer to a particular case of the cutter assignment problem as a "scenario." The *current* scenario is an examination of the port benefits associated with existing cutter assignments. To model the existing cutter assignments, all cutter assignment variables are fixed to reflect current assignments, forcing CAM to calculate port benefits without reassigning cutters.

The *optimal* scenario is the determination of the set of cutter assignments that maximizes port benefits, less relocation costs. CAM reassigns all cutters, as necessary, to arrive at an optimal solution. Relocation costs reflect moving cutters from current homeports to new ones.

Between these two extremes, we hope to discover partially or completely restricted scenarios for which CAM calculates an optimal solution subject to certain limitations. Partial restrictions are modeled most efficiently by modifying model parameters (e.g. setting Cape May, NJ, capacity to zero to reflect the restriction that no cutter be assigned there). An alternative to modifying parameters is the less efficient method of adding constraints to the base model. Using the Cape May example, a constraint is added that requires the total number of cutters assigned to Cape May to equal zero. This technique is less efficient due to the additional arithmetic demands it places on CAM, but it provides users with a clear audit trail of restrictions placed on the base model.

The use of additional constraints to model partially or completely restricted scenarios, in this assignment problem, has no noticeable impact on CAM's response time.

The Pacific and Atlantic Area problems are solved individually, respectively requiring port assignments for 15 and 28 cutters. Each area has 21 candidate ports.

The relocation scenarios that follow have been suggested by the Pacific Area Cutter Operations Staff and the Atlantic Area Cutter Force Branch and reflect a representative range of issues and concerns bearing on this large-scale problem. Tables 8 and 9 describe the scenarios CAM examines in this thesis.

PACIFIC AREA SCENARIOS	
SCENARIO	DESCRIPTION
CURRENT	EVALUATE CURRENT CUTTER ASSIGNMENTS ACCORDING TO CRITERIA
OPTIMAL	DETERMINE OPTIMAL CUTTER ASSIGNMENTS
OPTIMAL (MODIFIED)	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) 210' MEDIUM ENDURANCE CUTTERS DO NOT RELOCATE
ONE	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) 210' MEDIUM ENDURANCE CUTTERS DO NOT RELOCATE (B) HEC'S MOVE FROM SAN PEDRO TO ALAMEDA (C) HEC'S MOVE FROM SEATTLE TO BREMERTON (D) REMAINING HEC'S DO NOT RELOCATE
TWO	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) 210' MEDIUM ENDURANCE CUTTERS DO NOT RELOCATE (B) HEC'S MOVE FROM SAN PEDRO AND SEATTLE TO NAVSTA SAN DIEGO (C) REMAINING HEC'S DO NOT RELOCATE
THREE	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) 210' MEDIUM ENDURANCE CUTTERS DO NOT RELOCATE (B) HEC'S MOVE FROM SAN PEDRO, HONOLULU, AND SEATTLE TO NAVSTA SAN DIEGO (C) REMAINING HEC'S DO NOT RELOCATE
FOUR	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) 210' MEDIUM ENDURANCE CUTTERS DO NOT RELOCATE (B) HEC'S MOVE FROM SAN PEDRO TO ALAMEDA (C) REMAINING HEC'S DO NOT RELOCATE
FIVE	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) 210' MEDIUM ENDURANCE CUTTERS DO NOT RELOCATE (B) HEC'S MOVE FROM HONOLULU TO NAVSTA SAN DIEGO (C) REMAINING HEC'S DO NOT RELOCATE
SIX	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) 210' MEDIUM ENDURANCE CUTTERS DO NOT RELOCATE (B) HEC'S MOVE FROM SAN PEDRO AND SEATTLE TO BREMERTON (C) REMAINING HEC'S DO NOT RELOCATE

Table 8. Pacific Area scenarios. CAM has evaluated a variety of scenarios including the fixed existing (current) cutter assignments, an outright optimal relocation of all cutters, and a number of reasonable partially or completely restricted situations suggested by the Pacific Area future operations staff (USCG, 1997a).

ATLANTIC AREA SCENARIOS	
SCENARIO	DESCRIPTION
CURRENT	EVALUATE CURRENT CUTTER ASSIGNMENTS ACCORDING TO CRITERIA
OPTIMAL	DETERMINE OPTIMAL CUTTER ASSIGNMENTS
INITIAL	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) HEC'S REMAIN IN CHARLESTON,SC (B) VIGOROUS MUST LEAVE CAPE MAY
FINAL	DETERMINE OPTIMAL CUTTER ASSIGNMENTS SUBJECT TO: (A) HEC'S REMAIN IN CHARLESTON,SC (B) CAMPBELL & TAHOMA MOVE TO CHARLESTON (C) VIGOROUS MOVES TO NEWPORT (D) ONE 270' MEC MOVES FROM BOSTON TO CHARLESTON (E) TWO 270' MEC'S MOVE FROM BOSTON TO NEWPORT (F) DAUNTLESS MOVES TO PENSACOLA (G) COURAGEOUS MOVES TO PENSACOLA (H) VALIANT MOVES TO PENSACOLA (I) RELIANCE MOVES TO NEWPORT (J) DILIGENCE MOVES TO PORTSMOUTH

Table 9. Atlantic Area scenarios. CAM has evaluated a variety of scenarios including evaluating the fixed existing (current) cutter assignments, an outright optimal relocation of all cutters, and a number of reasonable partially-restricted situations suggested by the Atlantic Area cutter force staff (USCG, 1997c).

1. Current Scenario

The scores obtained by running the Pacific Area current scenario do not reveal any unexpected or surprising information. The Atlantic Area current scenario scores are artificially low because the existing homeports of New Castle, NH, Cape May, NJ, Wilmington, SC, Miami, FL, and Galveston, TX, are awarded no points because they have been identified as ports the Coast Guard desires to vacate (USCG, 1997c). The results are shown in Figures 5 and 6. Included in the figures is an indication of the gap between current criteria scores and perfect scores for each criterion. For example, the total Quality of Life (QOL) score earned by the 15 Pacific Area cutters is 916 points. If perfect scores were earned for QOL that total would be 1500 points (15 cutters X 100 maximum points).

It is important to note that perfect scores in all criteria are not possible. For many criteria, the highest number of points awarded to a port is less than the maximum possible.

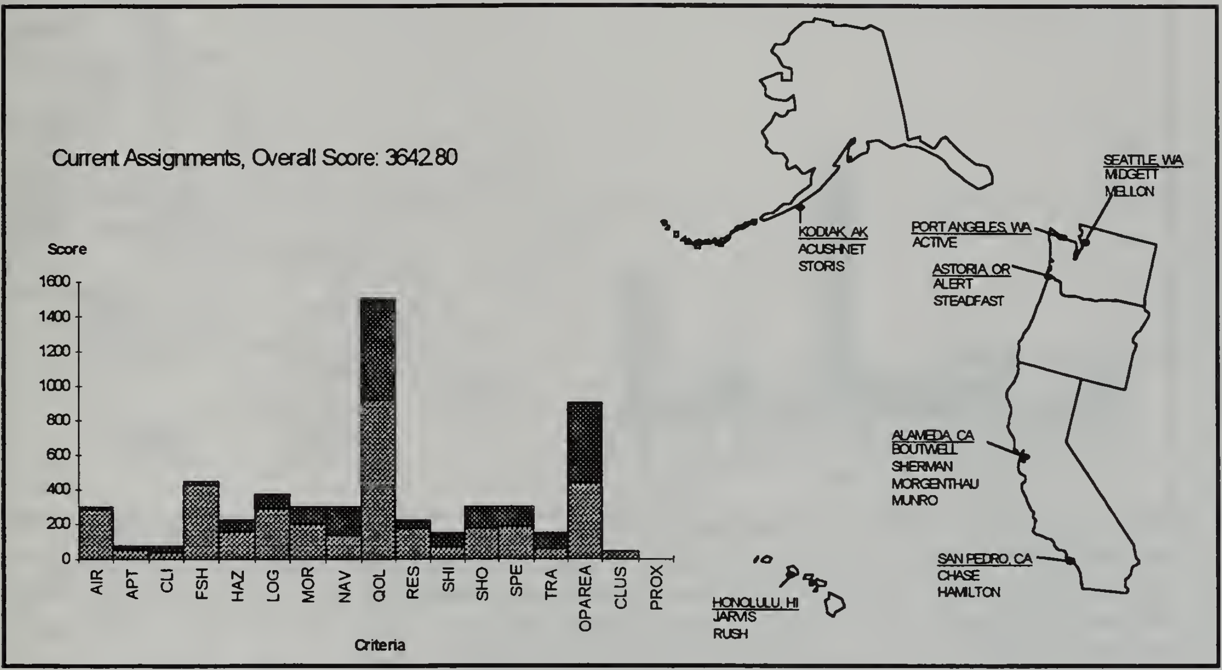

Figure 5. Current Pacific Area Assignments. The existing set of cutter assignments do not contain unexpected or surprising information. The dark gray regions indicate the gap between the current scenario score for each criterion and maximum score for each criterion. For instance, the Quality of Life (QOL) score now totals 916 points (shown in light gray), but might possibly be raised as high as 1500 points (light and dark gray).

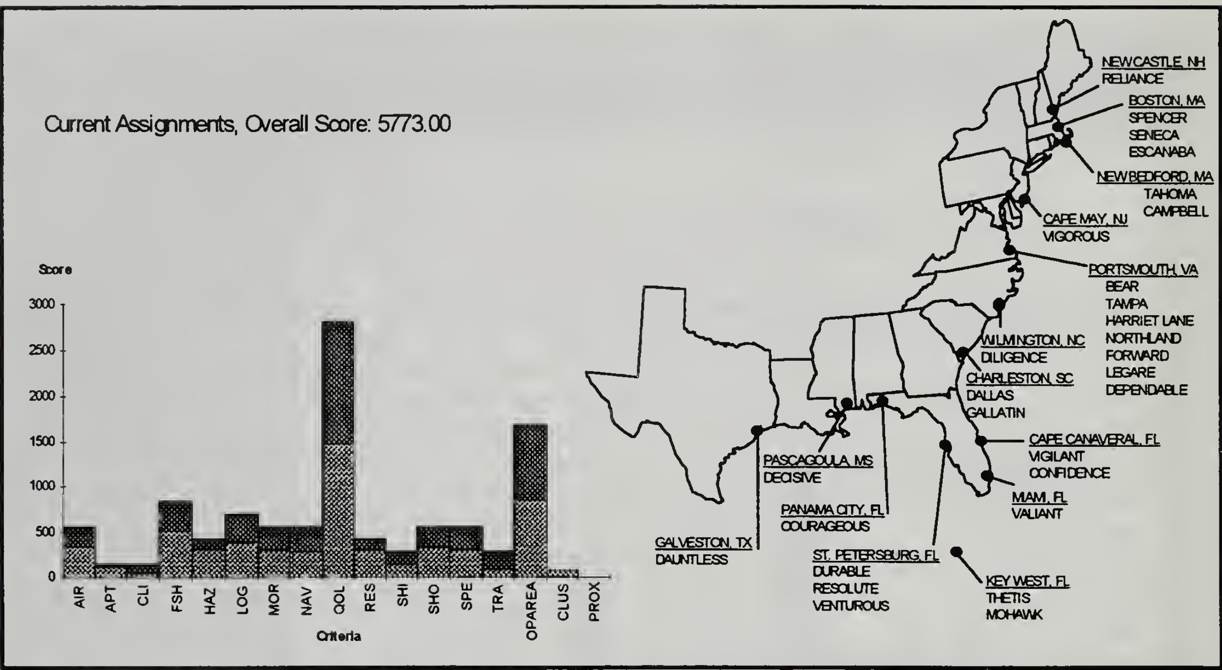

Figure 6. Current Atlantic Area Assignments. This score is artificially low due to the lack of benefit data for ports the Atlantic Area seeks to vacate. The dark gray regions indicate the gap between the current scenario score for each criterion and maximum score for each criterion. For instance, the Quality of Life (QOL) score now totals 1467 points (shown in light gray), but might possibly be raised as high as 2800 points (light and dark gray).

2. Optimal Scenario

CAM has next determined an optimal set of assignments for each area. In determining an optimal set of assignments, CAM appears to fill the highest rated ports to capacity. This indicates model benefits outweigh model relocation costs. The results are shown in Figures 7 and 8.

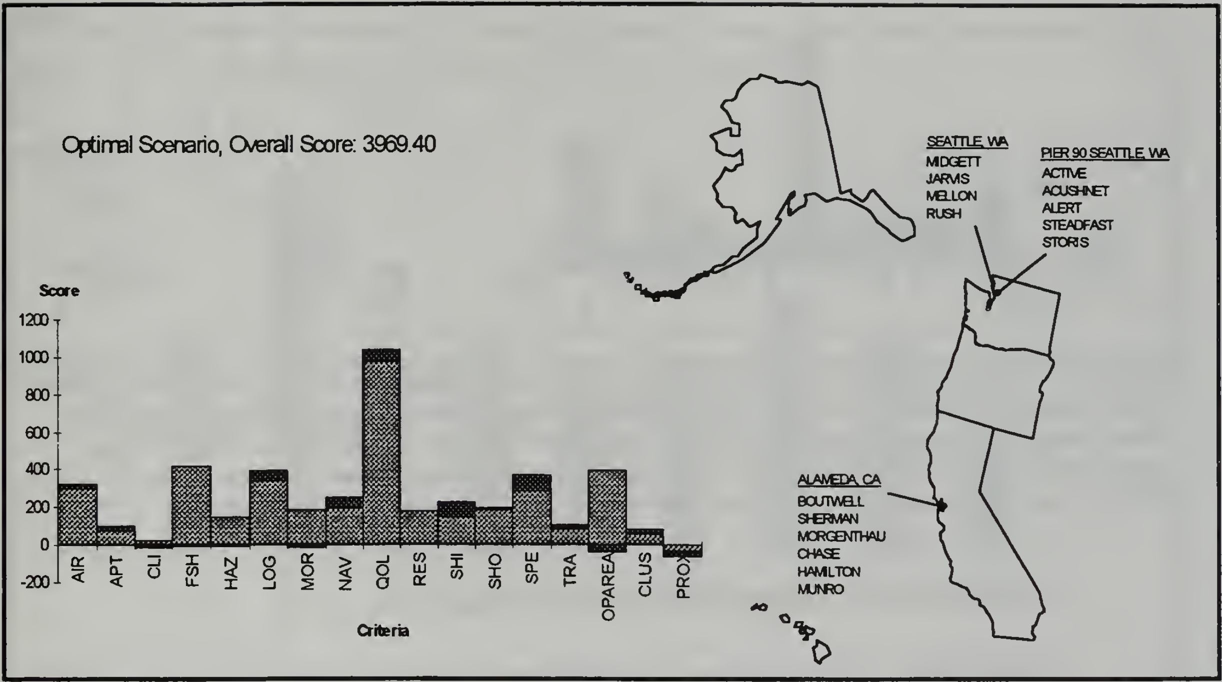

Figure 7. Pacific Area Optimal Assignments. Evidently, model benefits outweigh model relocation costs because this optimal solution fills the highest-rated ports to capacity (Alameda and Seattle are filled to capacity). This results in a migration of all vessels to Alameda, CA, and to Seattle, WA. The dark gray areas reflect how much change is made in each criterion when we compare the optimal scenario with the current scenario. A negative value indicates a decrease in criterion score.

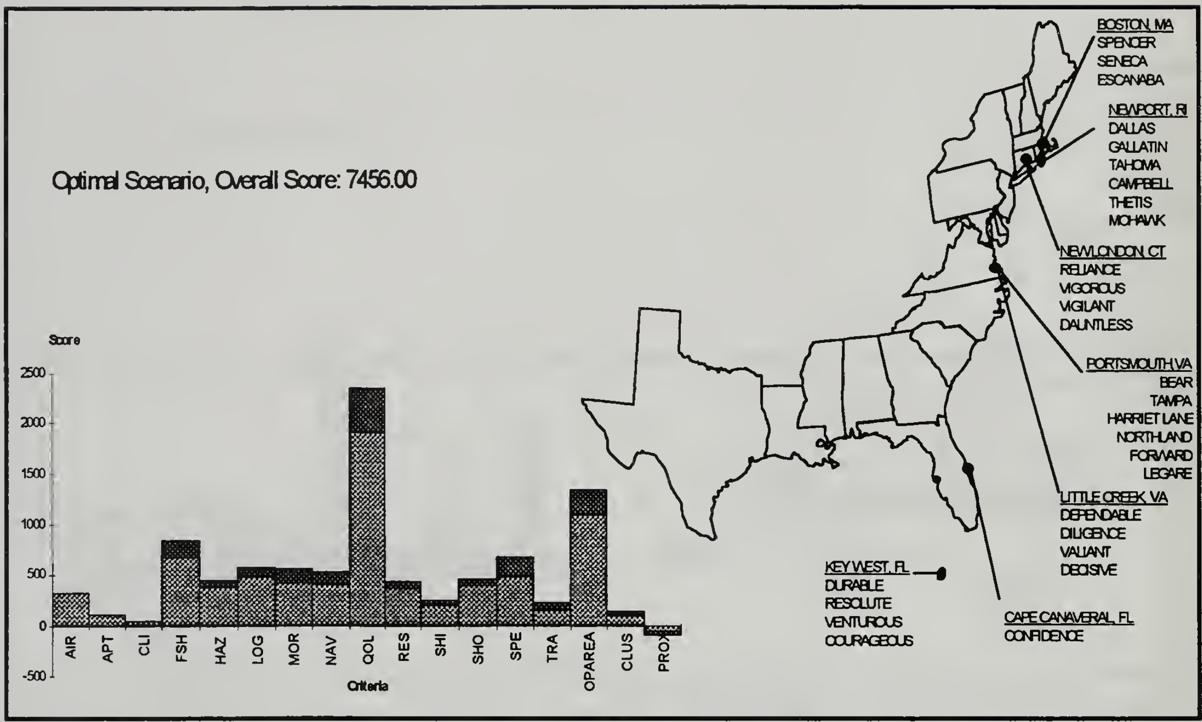

Figure 8. Atlantic Area Optimal Assignments. Again, model benefits outweigh model relocation costs because this optimal solution fills the highest-rated ports to capacity (Boston, Newport, New London, Portsmouth, Little Creek, and Key West are filled to capacity). The dark gray areas reflect how much change is made in each criterion when we compare the optimal scenario with the current scenario. A negative value indicates a decrease in criterion score.

3. Partially and Completely Restricted Scenarios

Optimal relocation and current relocation scenarios provide best and (presumably) worst case bounds for any reasonable partially or completely restricted scenarios. CAM's examination of the suggested restricted scenarios reveals a significant reduction in port benefits. The assignment sets for the scenarios, along with graphical results, are contained in Appendix A for Pacific Area scenarios and Appendix B for Atlantic Area scenarios. Figures 9 and 10 summarize the port benefit scores earned by each scenario.

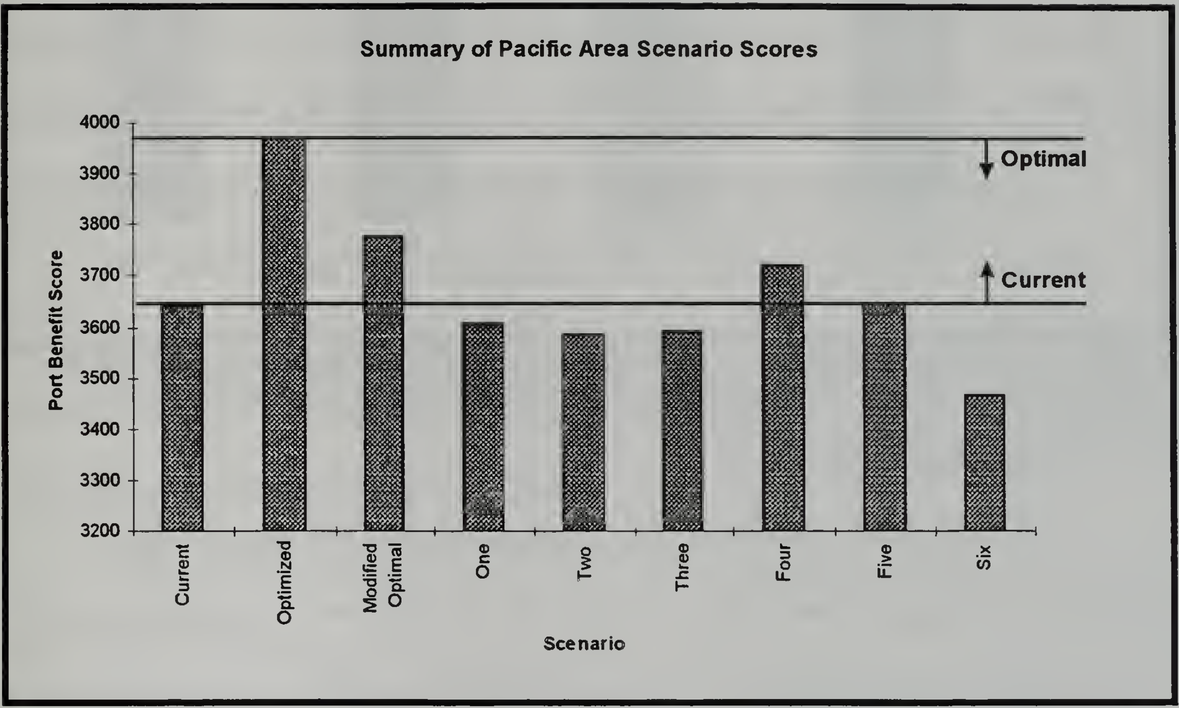

Figure 9. Summary of Pacific Area Scenario Scores. The current and optimal homeport locations provide perspective for the accompanying restricted scenarios. In some cases, the complete restrictions may seem reasonable enough, but following model criteria, make things worse than if we leave cutters where they are today. Clearly, some of these restrictions are surprisingly bad. This suggests that either the criteria scoring does not reflect the philosophy suggesting the restrictions, or that the restrictions are ill considered.

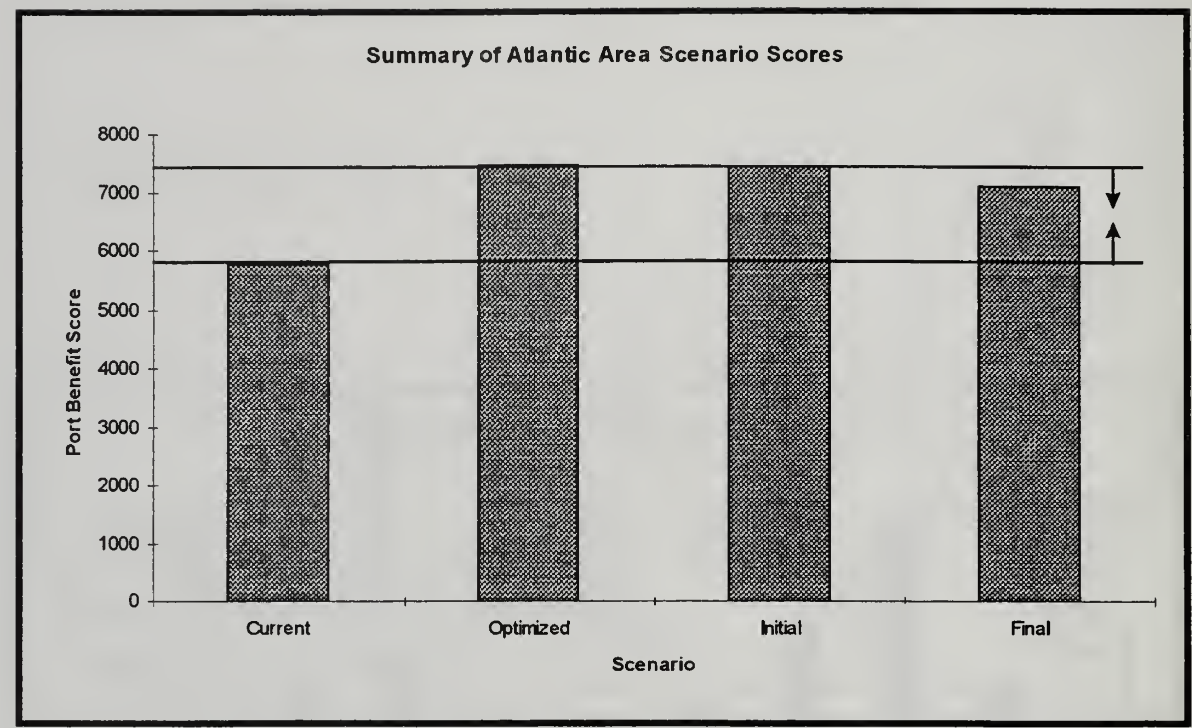

Figure 10. Summary of Atlantic Area Scenario Scores. The "initial" partial restriction that fixes high endurance cutters in current homeports is essentially as good as the optimal scenario.

B. MODEL RESPONSE TIME

CAM data can be modified for most scenarios in only a few minutes. Each scenario contains approximately 200 equations and 1000 variables. CAM optimizes each scenario in less than ten seconds on a 16 megabyte IBM compatible personal computer with a 486DX4 processor.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Using the port criteria developed by the Strategic Homeports Study Team, the Cutter Assignment Model (CAM) provides a set of cutter assignments with greater port benefits than the current set of cutter assignments or any of the partially restricted scenarios examined in this thesis. Additionally, CAM responds quickly and allows for the examination of numerous scenarios with minor modifications to the base model.

The addition or removal of cutters or types of cutters is easily accomplished in CAM. The structure of the index sets allows for individual cutters of existing types to be added, or removed. The structure of the model equations allows for a new type of cutter to be added, or removed, with minimal effort.

CAM can maximize a specified criterion while remaining near optimal with respect to all criteria. For instance, CAM is capable of maximizing OpArea scores subject to retaining at least 90% of overall optimal port benefits. The "90% of overall optimal" port benefits constraint can be added as an aspiration constraint, based on an optimal benefit level retained from an earlier optimization. Caution is a virtue when specifying multiple simultaneous aspiration constraints: we need to be sure that there are feasible solutions to these aspirations before requiring further optimization.

B. RECOMMENDATIONS

The decision aid presented in this thesis bases its assignment decisions on existing cutters and the criteria developed by the Strategic Homeports Study Team, Homeporting

Subgroup. The Cutter Assignment Model operates under certain assumptions regarding relocation costs and clustering benefits. CAM would benefit from additional information in a few key areas.

CAM uses estimated relocation costs. Actual relocation cost information could be transformed and used by CAM to better influence the relocation of cutters.

CAM applies the same linear clustering reward to every additional cutter in every port, just as advised by the Homeporting Subgroup. This does not reward or penalize clustering at all, making the term misleading. CAM can accommodate nonlinear rewards for clustering, which would be more accurate in the spirit of the term.

Judging from the partially restricted scenarios, CAM can forecast that some suggestions, although superficially appealing, would make things worse.

To maintain a level playing field between man and machine, the modeled results of a partially-restricted scenario should reflect expected results. When dramatic differences appear between expert human judgment and CAM, this suggests a fault in the criteria scoring system requiring re-examination.

CAM can aid, but not replace, the decision maker in achieving higher port benefits by providing speed, flexibility, consistency, accuracy, and optimal insight.

APPENDIX A. PACIFIC AREA SCENARIOS RESULTS

This appendix displays the results of the Pacific Area scenarios CAM examines in this thesis.

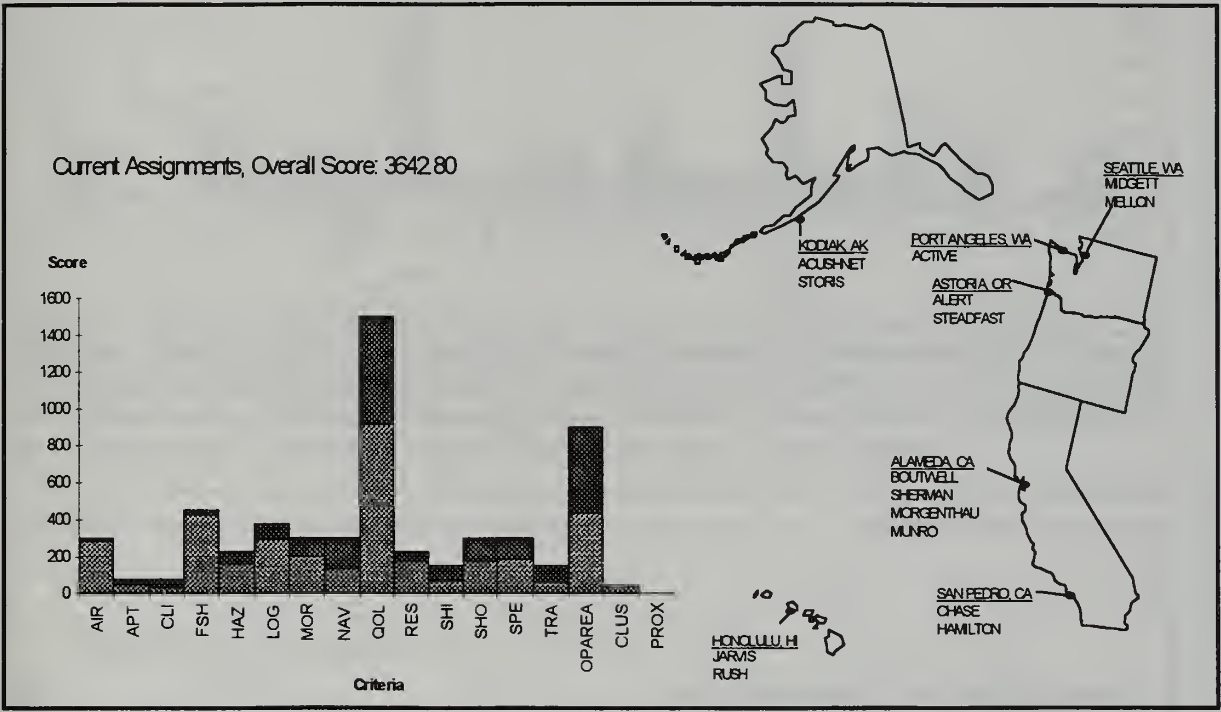

Figure 11. Current Assignments Scenario. CAM evaluates the current set of cutter assignments. The existing set of cutter assignments do no contain unexpected or surprising information. The dark gray regions indicate the gap between the current scenario score for each criterion and maximum score for each criterion. For instance, the Quality of Life (QOL) score now totals 916 points (shown in light gray), but might possibly be raised as high as 1500 points (light and dark gray).

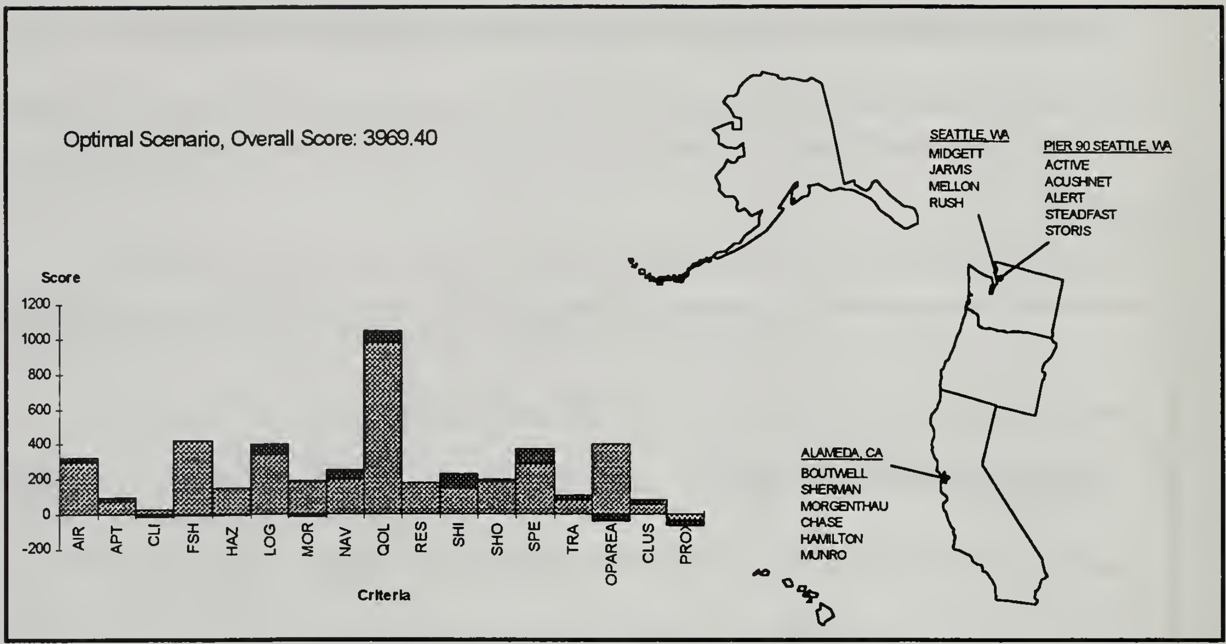

Figure 12. Optimal Scenario. CAM determines an optimal set of cutter assignments. The dark gray areas reflect how much change is made in each criterion when we compare the optimal scenario with the current scenario. A negative value indicates a decrease in criterion score.

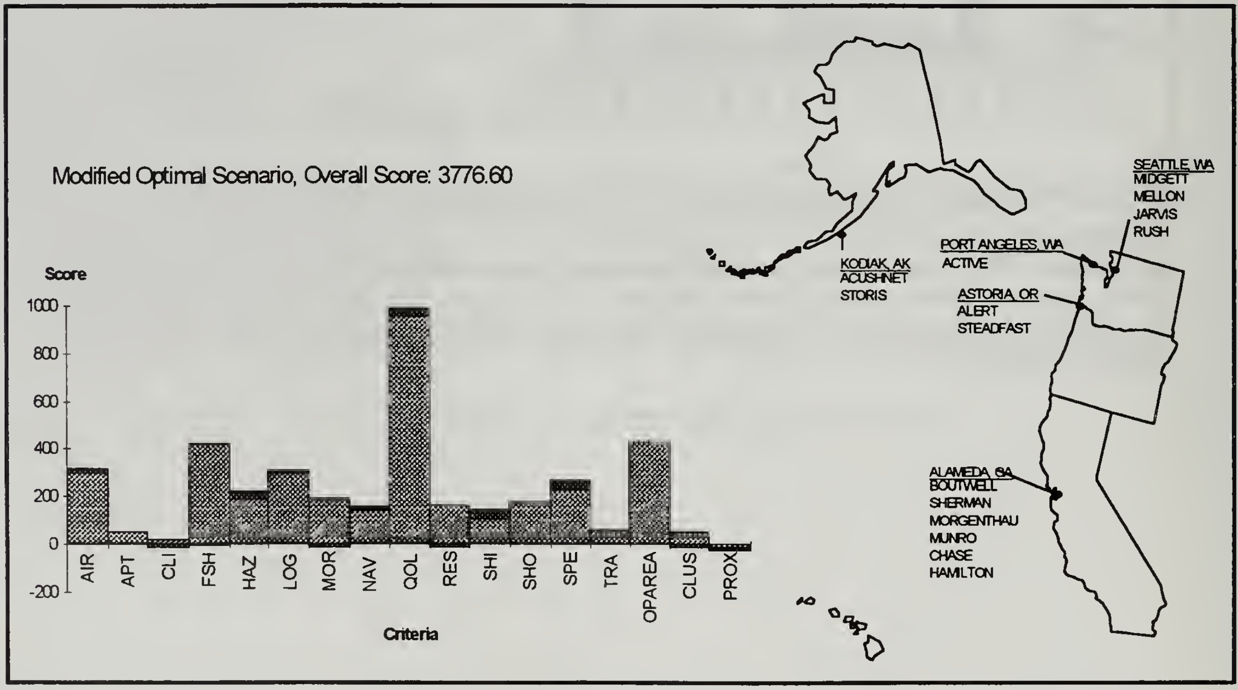

Figure 13. Modified Optimal Scenario. CAM determines the value of cutter assignments subject to keeping each 210' medium endurance cutter at its current homeports. The dark gray areas reflect how much change is made in each criterion when we compare the modified optimal scenario with the current scenario. A negative value indicates a decrease in criterion score.

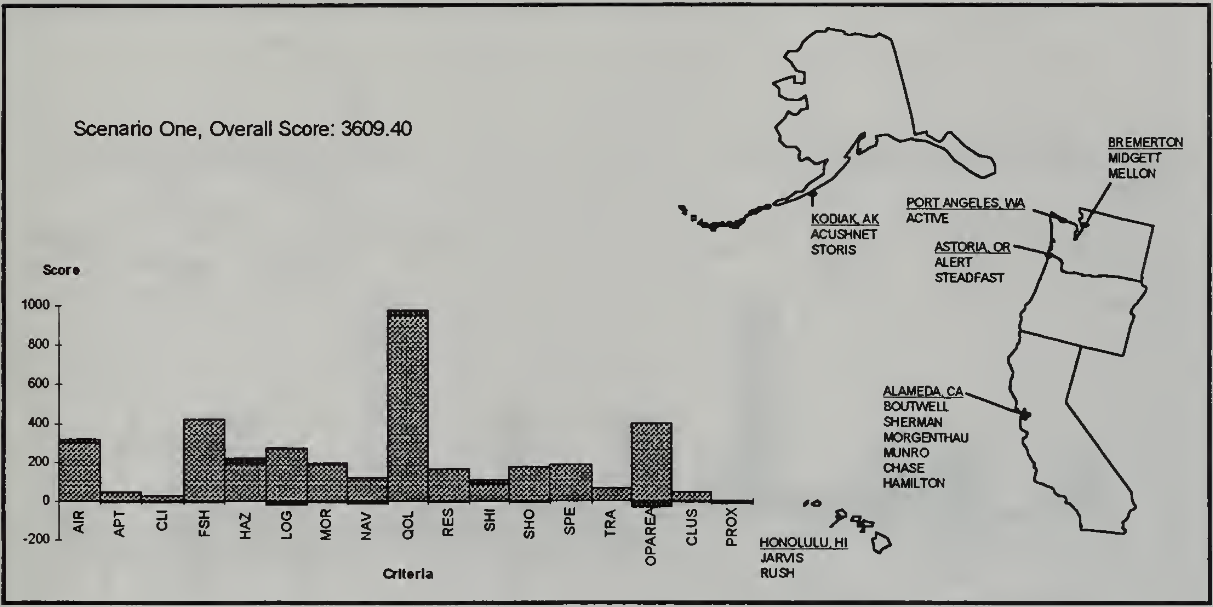

Figure 14. Scenario One. CAM evaluates cutter assignments subject to moving both high endurance cutters from San Pedro, CA, to Alameda, CA, moving both high endurance cutters from Seattle, WA, to Bremerton, WA, and keeping the remaining cutters in place. The dark gray areas reflect how much change is made in each criterion when we compare scenario one with the current scenario. A negative value indicates a decrease in criterion score.

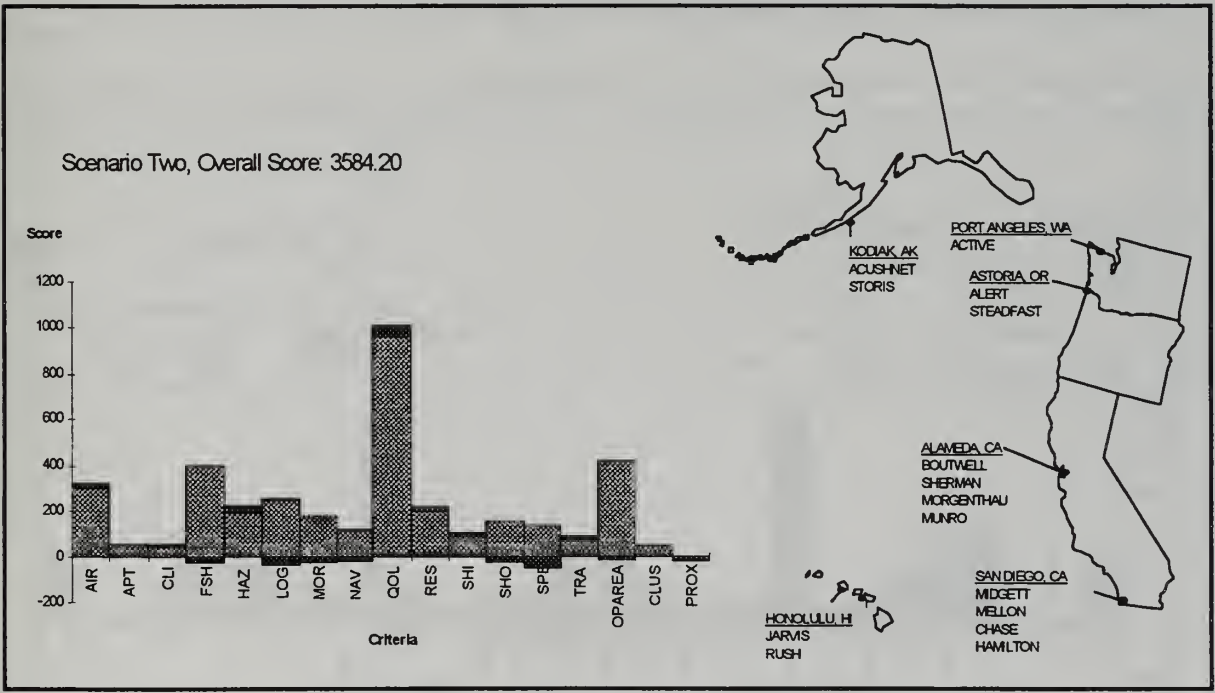

Figure 15. Scenario Two. CAM evaluates cutter assignments subject to moving all high endurance cutters now located in San Pedro, CA, and Seattle, WA, to NAVAL STATION San Diego, CA, and leaving remaining cutters in place. The dark gray areas reflect how much change is made in each criterion when we compare scenario two with the current scenario. A negative value indicates a decrease in criterion score.

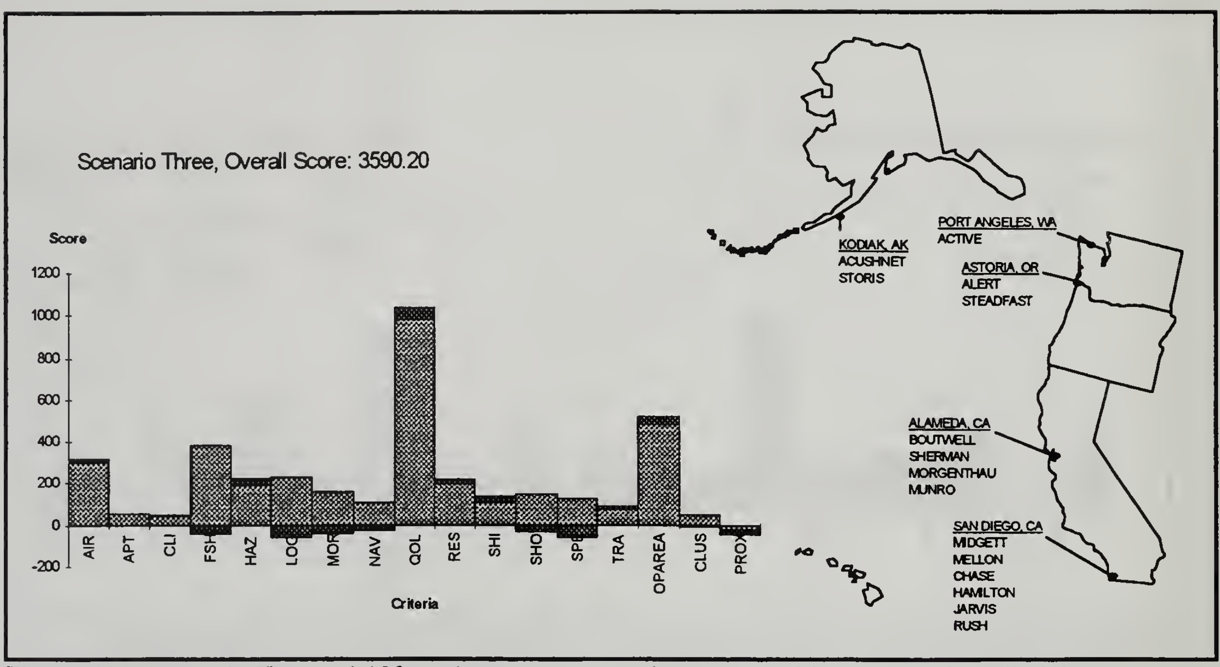

Figure 16. Scenario Three. CAM evaluates cutter assignments subject to moving all high endurance cutters now located in San Pedro, CA, Honolulu, HI, and Seattle, WA, to NAVAL STATION San Diego, CA, and leaving remaining in place. The dark gray areas reflect how much change is made in each criterion when we compare scenario three with the current scenario. A negative value indicates a decrease in criterion score.

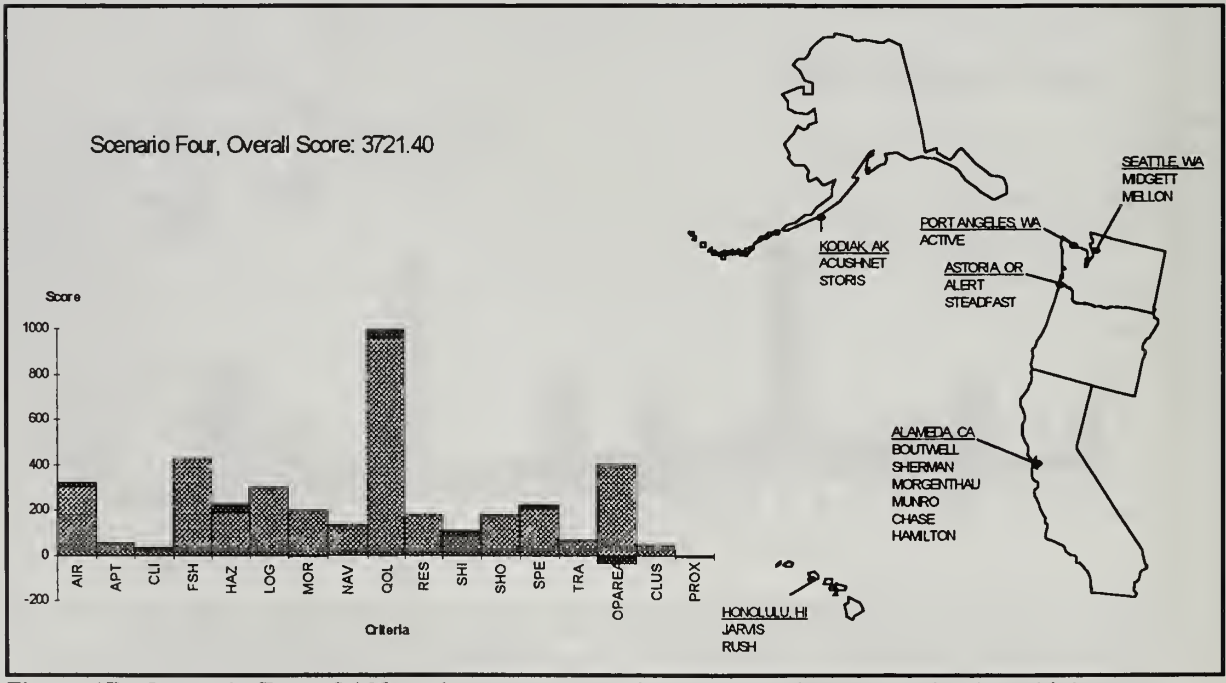

Figure 17. Scenario Four. CAM evaluates cutter assignments subject to moving both high endurance cutters from San Pedro, CA, to Alameda, CA, and leaving remaining cutters in place. The dark gray areas reflect how much change is made in each criterion when we compare scenario four with the current scenario. A negative value indicates a decrease in criterion score.

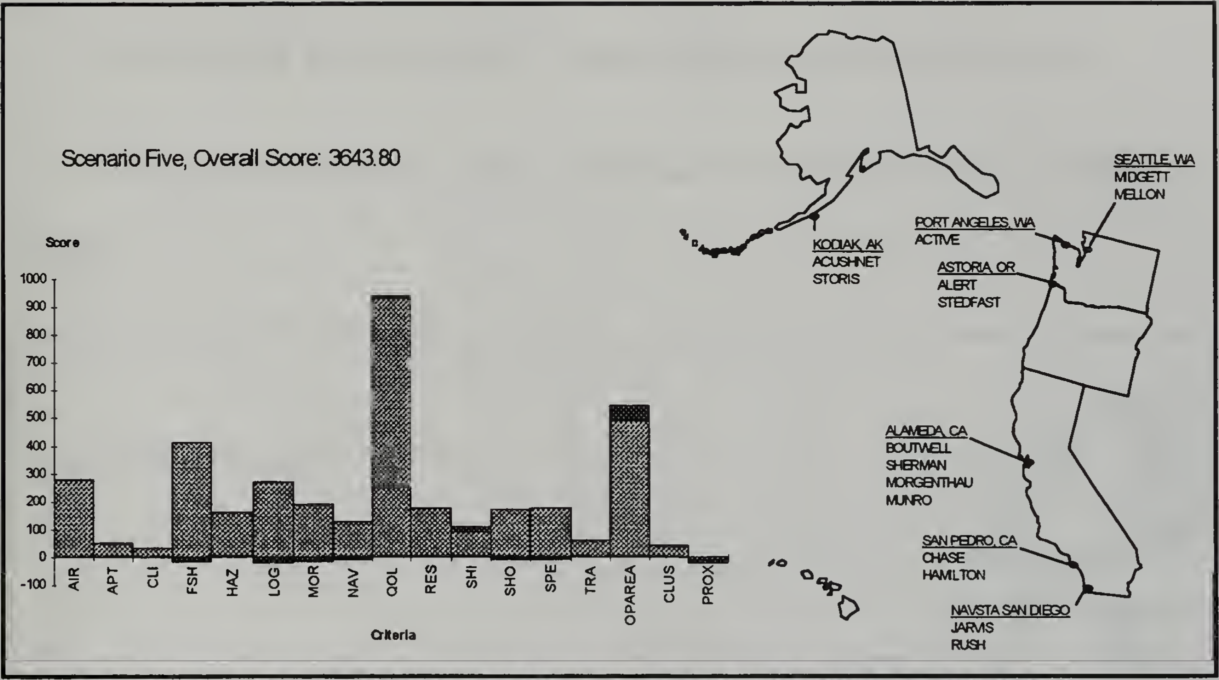

Figure 18. Scenario Five. CAM evaluates cutter assignments subject to moving both high endurance cutters from Honolulu, HI, to NAVAL STATION San Diego, CA, and leaving remaining cutters in place. The dark gray areas reflect how much change is made in each criterion when we compare scenario five with the current scenario. A negative value indicates a decrease in criterion score.

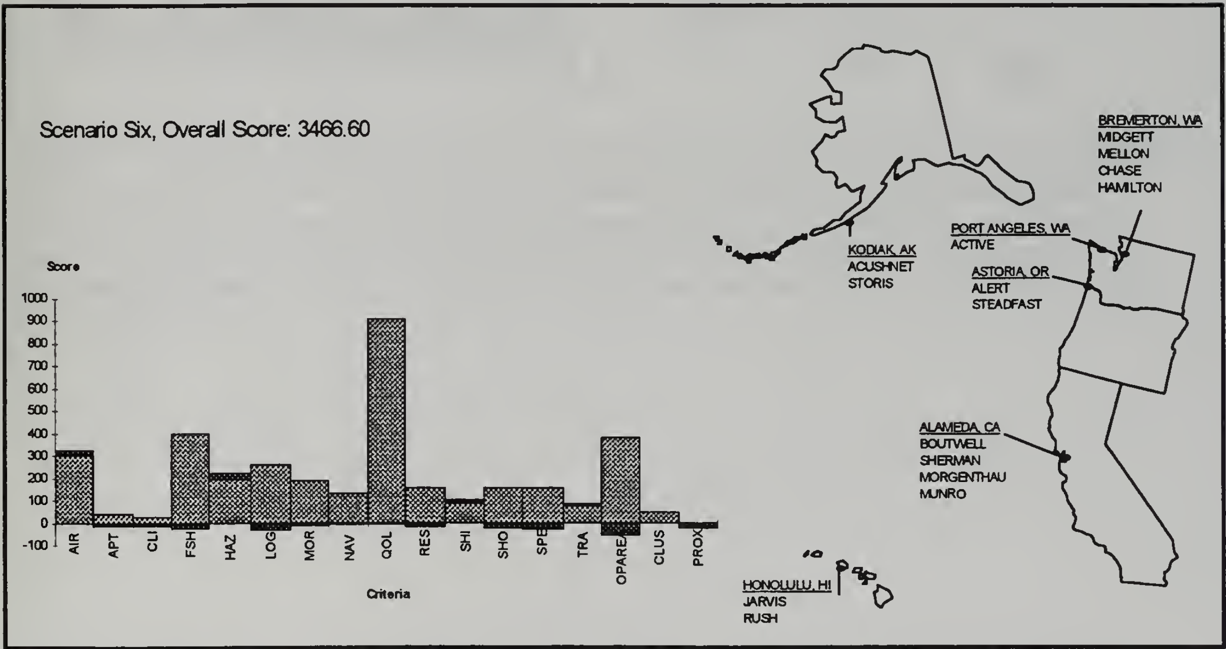

Figure 19. Scenario Six. CAM evaluates cutter assignments subject to moving high endurance cutters now located in San Pedro, CA, and Seattle, WA, to Bremerton, WA, and leaving remaining cutters in place. The dark gray areas reflect how much change is made in each criterion when we compare scenario six with the current scenario. A negative value indicates a decrease in criterion score.

APPENDIX B. ATLANTIC AREA SCENARIOS RESULTS

This appendix displays the results of the Atlantic Area scenarios CAM examines in this thesis.

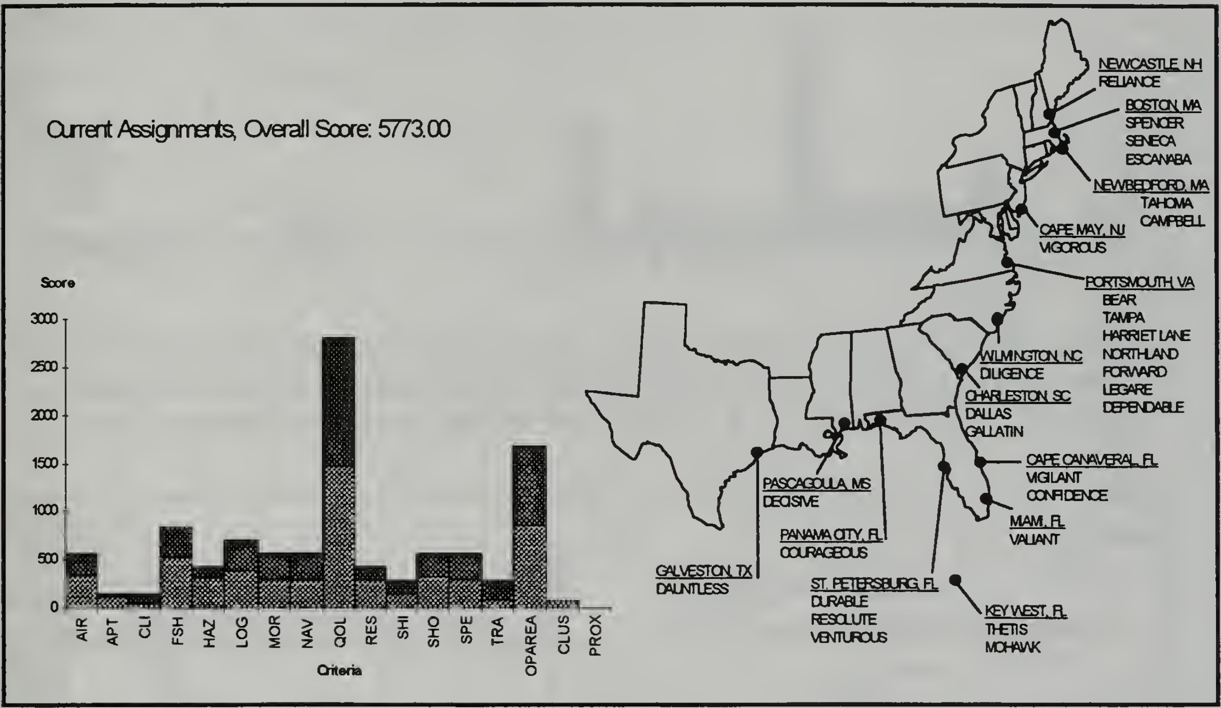

Figure 20. Current Assignments Scenario. CAM evaluates the current set of cutter assignments. This score is artificially low due to the lack of benefit data for ports the Atlantic Area seeks to vacate. The dark gray regions indicate the gap between the current scenario score for each criterion and maximum score for each criterion. For instance, the Quality of Life (QOL) score now totals 1467 points (shown in light gray), but might possibly be raised as high as 2800 points (light and dark gray).

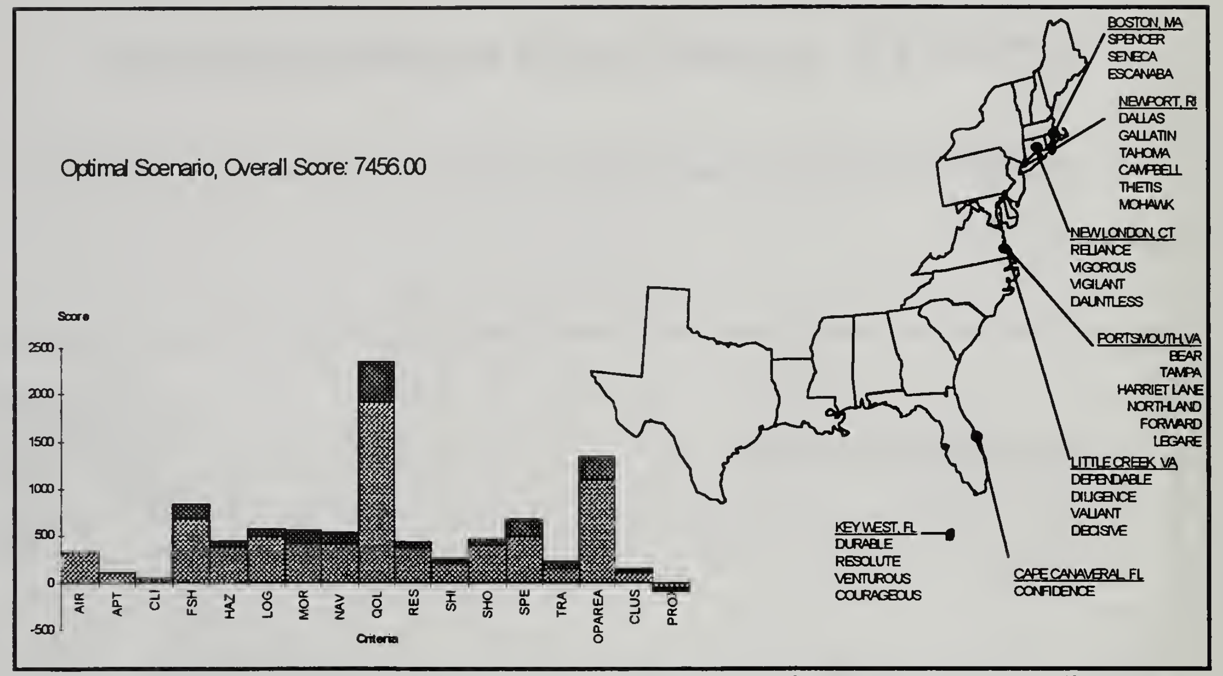

Figure 21. Optimal Scenario. CAM determines an optimal set of cutter assignments. The dark gray areas reflect how much change is made in each criterion when we compare the optimal scenario with the current scenario. A negative value indicates a decrease in criterion score.

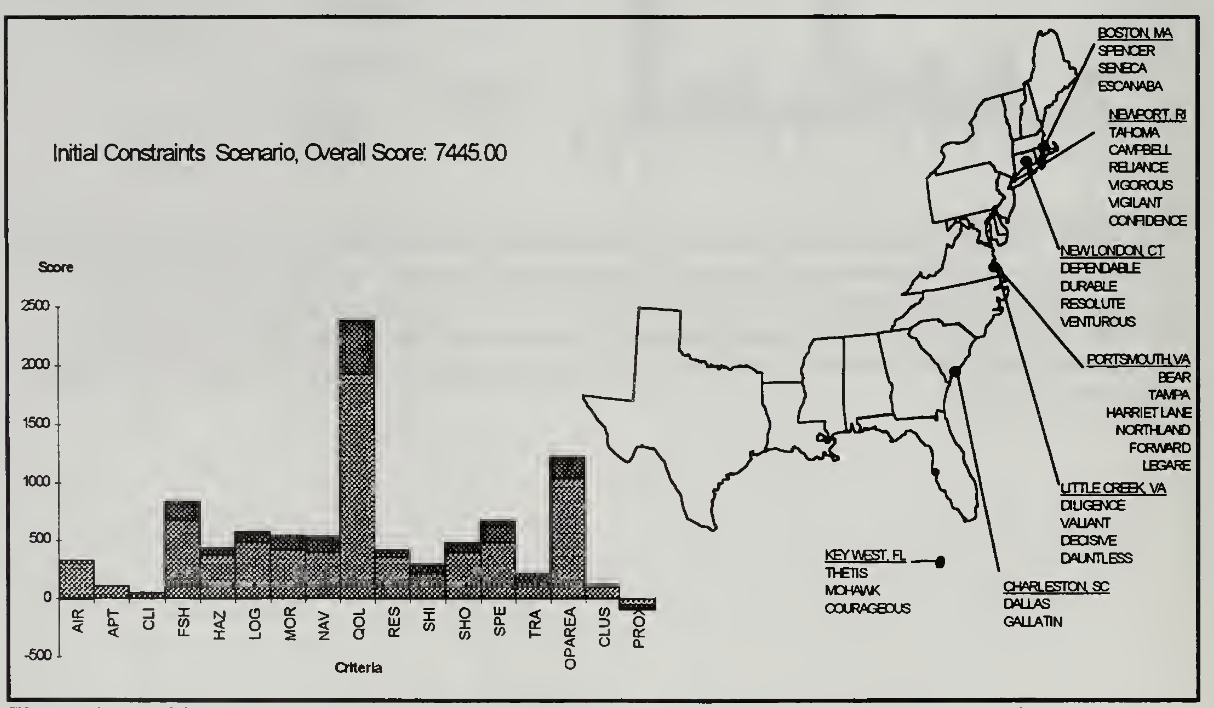

Figure 22. Initial Constraints Scenario. CAM determines an optimal set of cutter assignments subject to both high endurance cutters remaining in Charleston, SC, and USCGC VIGOROUS vacating Cape May, NJ (not to be replaced). The dark gray areas reflect how much change is made in each criterion when we compare the initial scenario with the current scenario. A negative value indicates a decrease in criterion score.

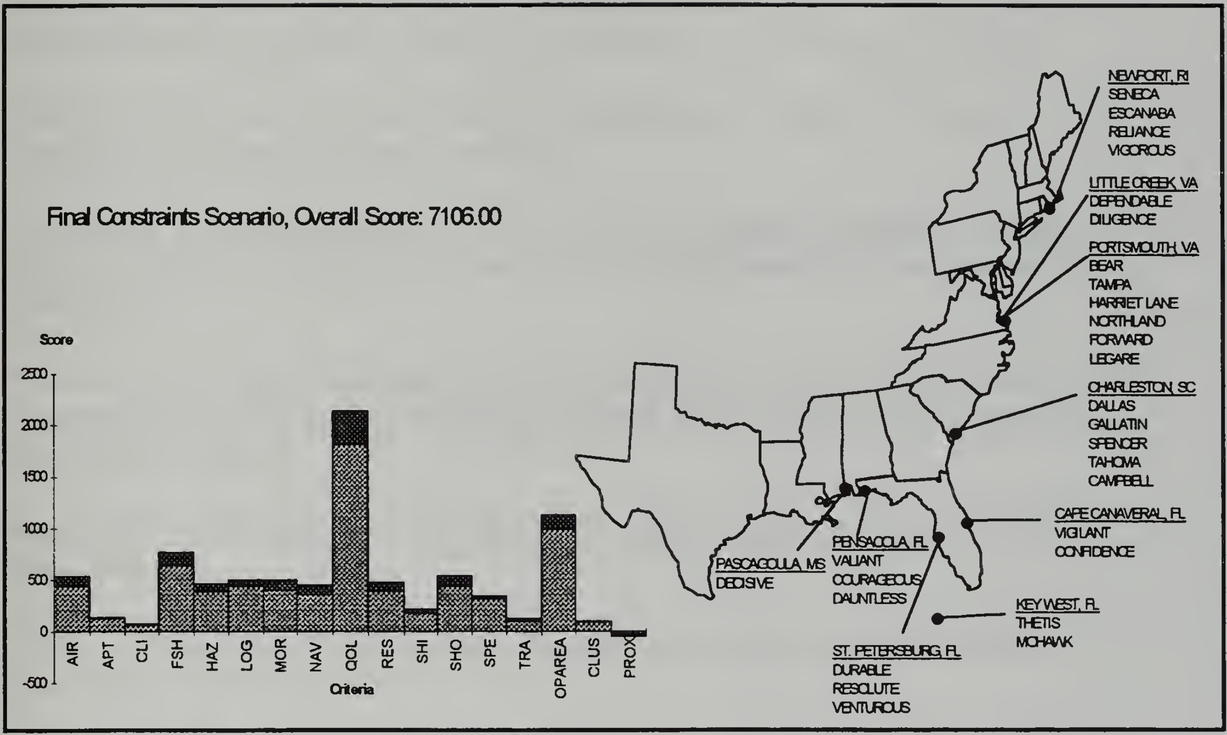

Figure 23. Final Constraints Scenario. CAM determines an optimal set of cutter assignments subject to both high endurance cutters remaining in Charleston, SC, USCGC CAMPBELL & USCGC TAHOMA relocating to Charleston, SC, USCGC VIGOROUS relocating to Newport, RI, one 270' medium endurance cutter in Boston, MA relocating to Charleston, SC, two 270' medium endurance cutters in Boston, MA relocating to Newport, RI, USCGC DAUNTLESS, USCGC COURAGEOUS and USCGC VALIANT relocating to Pensacola, FL, USCGC RELIANCE relocating to Newport, RI, and USCGC DILIGENCE relocating to Portsmouth, VA. The dark gray areas reflect how much change is made in each criterion when we compare the final constraints scenario with the current scenario. A negative value indicates a decrease in criterion score.

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